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Measurement of Radioactivity Concentration Levels of Natural Radio-nuclides in Soil Samples from Bethlehem Region - Palestine

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بسم الله الرحمن الرحيم

قال تعالى : (يرفع الله الذين آمنوا منكم والذين أوتوا العلم درجات) .

صدق الله العظيم

(المجادلة ١١)

Dedicated

To

My Parents

My Brothers and Sisters

With

Love

Declaration

I certify that the work presented in this thesis for the degree of master science in physics is the result of my efforts, and not have been presented for a higher degree to any other university or institution.

Signed :……....

Fatima Waleed Ibrahim Khrase

Date:

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Abstract

In this study we used HPGe detector to measure the activity concentrations of naturally occurring radio-nuclides ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in 50 soil samples collected from different sites in Bethlehem Governorate, Palestine.

The concentrations of ^{238}U, ^{232}Th and ^{40}K in the samples ranged 12.7-122.3; 1.8-32.2 and 1.6-183.8 Bq/kg with average values of 41.4±23.4, 19.5±8.1 and 113.3±47.4 Bq/kg, respectively. The concentrations of ^{232}Th and ^{40}K are lower than the measured world averages of 30 and 400 Bq /kg respectively, while the concentration of ^{238}U was higher than the world average of 35 Bq/kg.

The activity concentration of the fall-out ^{137}Cs, which is the only detected man made radionuclide, ranged 0.0-12.2 Bq/kg with an average value of 2.4±2.3 Bq/kg. The measured averages of gamma radiation absorbed dose rates of natural radio-nuclides (^{238}U, ^{232}Th and ^{40}K) including the contribution of ^{137}Cs and cosmic rays activities were 35.3 ±12.7 and 69.3±12.7 nGy/hr.

The average value for the total annual effective dose equivalent per person (D_{total}) is 0.28±0.10 mSv/y; the radium equivalent activity (Ra_{eq}) is 77.6±28.6 Bq/kg; the external hazard index (H_{ex}) is 0.21±0.08; the internal hazard index (H_{in}) is 0.32±0.14 and the radioactivity level index (I_{γ}) is 0.55±0.20. These values are lower than the corresponding world averages (0.48 mSv/y, 370 Bq/kg, 1, 1 and 1)

Table of Contents

List of Tables

List of Appendices

List of Figures

Definitions:

The following glossary are summarized from

http://www.bt.cdc.gov/radiation/glossary.asp; http://www.physics.isu.edu/radinf/terms.html

- **Absorbed dose , Radiation :** The amount of energy deposited by ionizing radiation in a unit mass of irradiated medium. It is expressed in units of joule per kilogram (J/kg), Gray (Gy) and rad where 1Gy=100rad.
- **Activity**: The rate of decay; the number of atoms that decay per unit of time. It is measured in units of Becquerel or Curie.
- **Alpha particle**: A charged particle consisting of two protons and two neutrons (a helium nucleus).
- **Background radiation**: Ionizing radiation from natural sources, such as terrestrial radiation due to radio-nuclides in the soil or cosmic radiation originating in outer space.
- **Becquerel (Bq)**: The international system of unit for activity, equal to one disintegration per second. Radioactivity is expressed in larger units like: thousands (kBq), one millions (MBq) or even billions (GBq) of becquerels. One Becquerel being equal to one disintegration per second, there are 3.7×10^{10} Bq in one curie.
- **Beta particles**: Electrons ejected from the nucleus of a decaying atom. Although they can be stopped by a thin sheet of aluminum, beta particles can penetrate the dead skin layer, potentially causing burns. They can pose a serious direct or external radiation threat and can be lethal depending on the amount received. They also pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled .
- **Biological half-life**: The time required for one half of the amount of a substance, such as a radionuclide, to be expelled from the body by natural metabolic processes.
- **Calibration**: The adjustment, as necessary, of a measuring device such that it responds within the required range and accuracy to known values of input.

- **Count**: A pulse that has been registered by a radiation detector. Counts correspond to an actual ionizing event.
- **Contamination (radioactive)**: The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people where it may be external or internal.
- **Curie (Ci):** The traditional unit of activity, and equals to 3.7×10^{10}, transformations in one second. The activity of 1 gram of radium is approximately 1 Ci. .
- **Dead time**: The time between two events, where either the detector, or electronics, cannot detect other incoming events .
- **Decay chain (decay series)**: A sequence of radioactive decays (transformations) beginning with one nucleus. The initial nucleus, the parent, decays into a daughter or progeny nucleus that differs from the first by particles emitted during the decay. If further decays take place, the subsequent nuclei are also usually called daughters or progeny. Sometimes, to distinguish the sequence, the daughter of the first daughter is called the granddaughter, etc .
- **Decay constant**: The mean number of radioactive nuclides that disintegrate in a unit of time. The decay constant is inversely proportional to the radioactive mean-life.
- **Decay, radioactive**: Disintegration of the nucleus of an unstable nuclide by an emission of charged particles and/or photons .
- **Detector**: A device that is sensitive to radiation and can produce a response signal suitable for measurement or analysis.
- **Dose equivalent**: A quantity that takes into effect 'radiation quality', relevant to the degree of damage caused by certain type of ionizing radiation. An equivalent dose is obtained by multiplying the absorbed dose by a radiation weighting factor or quality factor. The resulting quantity is expressed numerically in Sieverts (Sv) or in the old units of Rem. The quantity is independent of the absorbing material (i.e. tissue).

- **Dose rate**: Absorbed dose delivered per unit time.
- **Dosimetry**: Quantification of radiation doses to cells, tissues, organs, individuals or populations resulting from radiation exposures.
- **Effective dose:** The effective dose is obtained by taking the dose equivalent and multiplying by a tissue weighting factor which relates to the organs / tissues under consideration. Effective dose can be considered a doubly weighted absorbed dose since it takes into account the type of radiation (radiation weighting factor) and the target organ / tissue. The quantity can be used to express detriment to the whole body as a summation of several different doses of radiation with varying radiation weighting factors (radiation types) and targets. The unit of effective dose is the sievert Sv =1 J/kg.
- **Energy resolution of the detector:** the full width at halfe maximum of a distribution (FWHM) divided by the value of the peak centroid.
- **Exposure (radiation):** Is a measure of the ionization produced in air by x or gamma radiation; the sum of the electric charges on all ions of one sign produced in air when all electrons liberated by photons in a volume of air are completely stopped in air (dQ), divided by the mass of the air in the volume (dm). The unit of exposure in air is the roentgen, or coulomb per kilogram (SI units). One roentgen is equal to 2.58×10^{-4} coulomb per kilogram (C/kg).
- **Exposure pathway**: A route by which a radionuclide or other toxic material can enter the body. The main exposure routes are inhalation, ingestion, absorption through the skin, and entry through a cut or wound in the skin.
- **External exposure:** Exposure to radiation outside the body.
- **Fallout, nuclear**: Minute particles of radioactive debris that descend slowly from the atmosphere after a nuclear explosion.

- **Gamma rays**: High-energy electromagnetic radiation emitted by certain radio-nuclides when their nuclei transition from a higher to a lower energy state. Gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify gamma emitters present in a sample. Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage.
- **Genetic Effect of Radiation:** Inheritable change, chiefly mutations, produced by the absorption of ionizing radiation by germ cells. Genetic effects have not been observed in any human population exposed at any dose level.
- **Gray (Gy):** The international system of units for absorbed dose defined as one joule of energy absorbed per kilogram of material. The unit Gy can be used for any type of radiation, but it does not describe the biological effects of the different radiations.
- **Half-life, Radioactive:** The time required for a radioactive substance to lose 50% of its activity by decay. Each radio-nuclide has a unique physical half-life.
- **Ingestion:** Swallowing radio-nuclides or chemicals by eating or drinking.
- **Inhalation:** Breathing radio-nuclides or chemicals.
- **Intake:** In bioassay measurements, the quantity of radioactive material entering the body, principally by ingestion, inhalation, or absorption through intact or wounded skin.
- **Intensity**: Energy per unit time passing through a unit area perpendicular to the line of propagation at the point of interest .
- **Internal exposure:** Exposure to radioactive material taken into the body.
- **Ionizing radiation:** Electromagnetic or particulate radiation with sufficient energy to create ionization in a material .
- **Irradiation:** Exposure to radiation.

- **Non-ionizing radiation:** radiation that has lower energy and longer wavelengths than ionizing radiation. It is strong enough to heat tissue and can cause harmful biological effects. Examples include radio waves, microwaves, visible light, and infrared light.
- **NORM (Naturally Occurring Radioactive Materials)** : NORM is an acronym for naturally occurring radioactive materials comprising radioactive elements found in the environment. Long lived radioactive elements of interest include Uranium, Thorium and Potassium and any of their respective radioactive decay products such as radium and radon. Some of these elements have always been present in the earth's crust and within the tissues of all living beings. Although the concentration of NORM in most natural substances is low, higher concentrations may arise as the result of human activities .
- **Rad:** An energy deposition of 100 ergs per gram (or 0.01 joule per kilogram) of absorbing material.
- **Radiation**: Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. Radiation may be classified as either Ionizing or Non-Ionizing Radiation .
- **Radioactive material:** Material that contains unstable (radioactive) atoms that give off radiation as they decay.
- **Radioactivity:** The process of spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles often accompanied by gamma rays. This process is referred to as decay or disintegration of an atom.
- **Radiological or radiologic:** Related to radioactive materials or radiation. The radiological sciences focus on the measurement and effects of radiation.
- **Radionuclide**: An atom having a combination of neutrons and protons which cause the nucleus to be unstable .

- **Radiation Weighting Factor:** A factor expressing the relative effectiveness of a particular kind of radiation in producing biological damage. This factor is determined by the US Nuclear Regulatory Commission (NRC).
- **Roentgen equivalent, man:** a unit of equivalent dose. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. It is determined by multiplying the number of rads by the quality factor, a number reflecting the potential damage caused by the particular type of radiation. The rem is the traditional unit of equivalent dose, but it is being replaced by the sievert (Sv), which is equal to 100 rem.
- **Risk:** the probability of injury, disease, or death under specific circumstances and time periods. Risk can be expressed as a value that ranges from 0% (no injury or harm will occur) to 100% (harm or injury will definitely occur). Risk can be influenced by several factors: personal behavior or lifestyle, environmental exposure to other materials, or inborn or inherited characteristic known from scientific evidence to be associated with a health effect. Because many risk factors are not exactly measurable, risk estimates are uncertain.
- **Risk assessment** : an evaluation of the risk to human health or the environment by hazards. Risk assessments can look at either existing hazards or potential hazards.
- **Roentgen (R):** A unit of exposure to x-rays or gamma rays. One roentgen is the amount of gamma or x-rays needed to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.
- **Secular Equilibrium**: If a parent element has a very much longer half-life than the daughters (so there is not appreciable change in its amount in the time interval required for later products to attain equilibrium) then, after equilibrium is reached, equal

numbers of atoms of all members of the series disintegrate in unit time. This condition is never exactly attained, but is essentially established in such a case as ^{226}Ra and its transformation series to stable ^{206}Pb. The half-life of ^{226}Ra is about 1,600 years; of ^{222}Rn, approximately 3.82 days, and of each of the subsequent members, a few minutes. After about a month, essentially the equilibrium amount of radon is present; then (and for a long time) all members of the series disintegrate the same number of atoms per unit time. At this time, the activity of the daughter is equal to the activity of the parent.

- **Shield**: Material used to reduce the intensity from a source of radiation .
- **Sievert (Sv)**: The SI unit. The dose equivalent is equal to the absorbed dose, in gray, multiplied by the quality factor (1 sievert equals 100 rem). it is the SI unit for effective dose equivalent, which is the sum of the products of the dose equivalent to each organ or tissue and its corresponding tissue weighting factor .
- **Terrestrial radiation**: Radiation emitted by naturally occurring radioactive materials, such as uranium (U), thorium (Th), and radon (Rn) in the earth.
- **Tissue weighting factor**: Is an ICRP multiplier use to determine the effective dose from the equivalent dose in one or more organs or tissues. The factor takes account of the different sensitivities of organs and tissues for induction of probabilistic effects from exposure to ionizing radiation (principally causing cancer).
- **Uptake**: The taking of radioactive material into a person through inhalation, ingestion, absorption, or injection.
- **Whole body exposure**: an exposure of the body to radiation, in which the entire body, rather than an isolated part, is irradiated by an external source.

Abbreviations and Symbols

A	Activity of a group of atoms
ADC	Analog-to-Digital Converter
AEDE	Annual Effective Dose Equivalent
B.G.	Background
Bq	Becquerel
C	Net count rate
Ci	Curie
DCD	Detector Cryostat and Dewar
D_{indoor}	Indoor annual effective dose equivalent
disin/sec	Disintegration per second
$D_{outdoor}$	Outdoor annual effective dose equivalent
E	Energy
EC	Electrical Conductivity
eV	electron volt
Fig.	Figure
Gy	Gray
H_{ex}	External hazard index
H_{in}	Internal hazard index
HPGe	Hyper Pure Germanium
I	Number of gamma rays per disintegration
Iγ	Radioactivity level index
ICRU	International Commission on Radiation Units and Measurements
kCi	kilocurie
keV	kilo electron volt

M	Mass of soil Sample
MBq	Mega Becquerel
MCA	Multi Channel Analyzer
MCB	Multi Channel Buffer
mCi	Millie Curie (10^{-3} curie)
MeV	Mega electron volt
mSv	Millie sieverts
ms/cm	mili-seimens per centimetre
NORM	Naturally Occurring Radioactive Materials
nCi	nanocurie (10^{-9} curie)
PC	Personal Computer
PCI	Peripheral Component Interconnect
pCi	Picocurie
R	Roentgen
Rad	radiation absorbed dose
Ra_{eq}	Radium Equivalent Activity
Rem	Roentgen equivalent man
RBE	Relative Biological Effectiveness
Sv	Sievert
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
W_R	Radiation weighting factor
W_T	Tissue weighting factor
ε	Detection efficiency
μCi	microcurie (10^{-6} curie)

Chapter One

Radioactivity and Radiological Effects

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1. 1 Introduction

Radiation is energy in the form of particles or rays such as electromagnetic (EM) waves given off by unstable nuclides and transmitted through space. Any unstable nuclide is known as radioactive nuclide, and material having such nucleus is called radioactive materials. Thus, radioactivity is a general term used to describe a process in which radioactive nuclides release excess energy in the form of particles or radiation.

Radiation and radioactive materials are part of humans environment and affects his daily life since the done of era. We live in an environment in which natural as well as manmade radiations are present everywhere. On one hand, the natural sources include radioactive radon gas that we breathe, radioactive elements such as potassium-40 (^{40}K) that is found in many foods (including salt), uranium-238 (^{238}U) series and thorium-232 (^{232}Th) series which are found in soils and building materials, and cosmic rays that continually bombard us from outer space(UNSCEAR,1993; UNSCEAR,2000). Together, these are known as background radiation (UNSCEAR, 1993). Everyone is exposed to background radiation daily and our bodies contain radioactive nuclides such as carbon-14 (^{14}C), potassium-40 (^{40}K) and polonium-210 (^{210}Po) quite naturally (Dabayneh, 2008).

All life on earth has evolved in the presence of this radiation. For instance, light and heat and all types of solar radiations are essential to our existence. On the other hand, radiation and radioactive materials are produced by many human activities. Radiation is produced by x-ray equipment and by particle accelerators used in research and medicine. Radioactive materials are produced in nuclear reactors and particle accelerators. Fallout from nuclear

explosives testing, and small quantities of radioactive materials released to the environment from coal and nuclear power plants, are also sources of radiation exposure to man. Figure 1.1 is a pie chart showing the contribution size in percentage of each component of the background radiation doses received by the average Canadian (Canada: Living with radiation AECB,1995) or USA citizens (UNSCEAR, 2000).

Soils and rocks contribute to environmental radioactivity in two ways. Firstly, external dose is received by direct exposure to gamma radiation (whole body dose) and in some cases by beta radiation (skin dose) . Secondly, internal dose is received by inhalation of the radioactive daughters of radon gas, which is released from soil and the ingestion of ^{40}K, ^{238}U and ^{232}Th series radio-nuclides present in food and drinking water (Cooper et al., 2003).

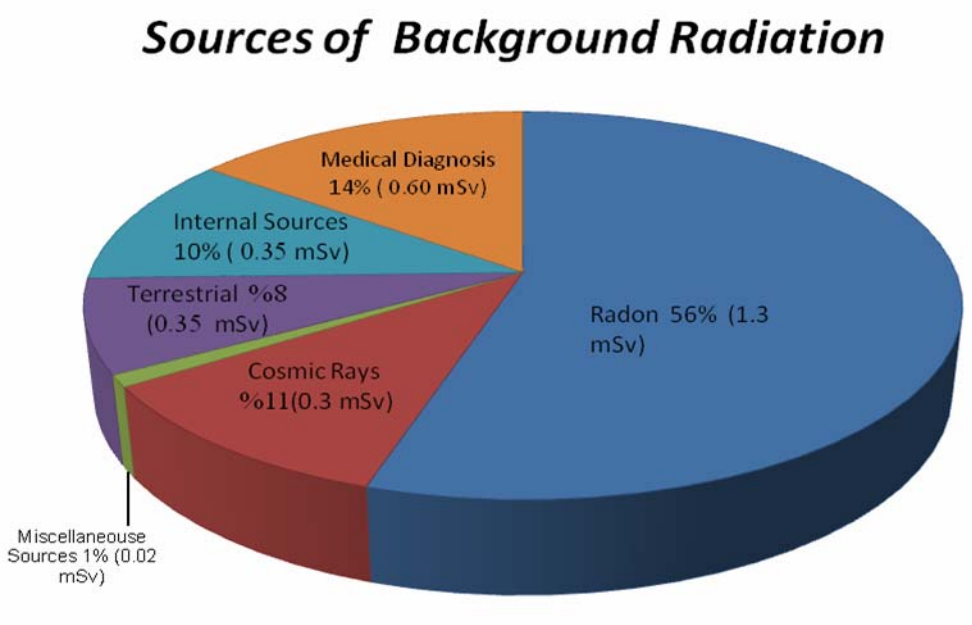


Fig.1.1: Sources and average distribution of natural background radiation for the world population (UNSCEAR, 2000).

The extraterrestrial radioactivity is emitted by cosmogony radio-nuclides such as ^{3}H, ^{7}Be, ^{14}C and ^{22}Na, which they are produced by the interaction of cosmic ray particles (mainly

high energetic protons) in the earth's atmosphere. The dose from cosmic radiation varies in different parts of the world according to differences in altitudes and the effects of the earth's magnetic field (Cooper et al., 2003). The absorbed dose in air from cosmic radiation outdoors at sea level is about 30 nGy/h for the southern hemisphere (UNSCEAR,2000).

We can classify radiation according to the effects it produces on matter, into ionizing and non-ionizing radiation. Ionizing radiation includes cosmic rays, X-rays and gamma radiation from radioactive materials. Non-ionizing radiation includes ultraviolet light, radiant heat, radio waves and microwaves.

The discovery of ionizing radiation and radioactive materials has led to a wide range of research topics in industry, agriculture, medicine, ---etc. Nowadays, radiation is a common and valuable tool in medicine, research and industry. It is used in medicine to diagnose illnesses, and in high doses, to treat diseases such as cancer. Also, high doses of radiation are used to kill harmful bacteria in food and to extend the shelf life of fresh produce. Radiation produces heat that is used to generate electricity in nuclear power reactors. Radioactive materials are used in a number of consumer products, such as smoke detectors and exit signs, and for many other research and industrial purposes.

Nevertheless, they can be harmful to life on earth, and people must be protected from unnecessary or excessive exposures. The greatest concern about ionizing radiation stems from its potential to cause malignant diseases in people exposed to it and inherited defects in the following generations. Our senses can not detect radiation, making this invisible risk seem even more insidious. The likelihood of such effects depends on the amount of radiation that a person receives, whether from natural or artificial sources. Radiation is one cause, among many, of the “dead disease” cancer.

So in circumstances that we can control, we need to make a careful balance between the benefits and the risks of the procedures that expose people to radiation. Thus, the benefits and risks of any activity involving radiation need to be investigated, so that an informed judgment can be made on its use, and any risks minimized. As the effects of ionizing radiation have become better understood, a system of radiological protection has been developed to protect people from exposure to sources of radiation, but public anxiety still remains.

The aim of this chapter is to help by providing information for those who are not experts. In the following sections, we shall describe briefly the sources and effects of ionizing radiation of all types as expressed in terms of radiation units used. Furthermore, the impact of radiation on humans and environment will be discussed briefly and the principles and practices of radiological protection will be explained.

1.2Radiation and radioactivity

Radioactive materials, also known as radio-nuclides or radioisotopes, are atoms that are unstable. In nature, there is a tendency for unstable atoms to change into a stable form by emitting excess radiation. Nuclides with too many neutrons tend to transform themselves to a more stable structure by converting a neutron to a proton; this process is known as beta decay, results in the emission of a negatively charged electron called a beta particle. Nuclides with too many protons convert the excess protons to neutrons in a different form of beta decay; they lose positive charge through the emission of a positron, which is a positively charge electron.

These transformations often leave the nucleus with excess energy that it loses as gamma rays-high energy photons, which are discrete parcels of energy without mass or charge.

Some heavy nuclides decay by producing an alpha particle consisting of two protons and two neutrons. Identical with a nucleus of helium, the alpha particle is much heavier than the beta particle and carries two units of positive charge.

The spontaneous transformation of a nucleus is called radioactivity, and the excess energy emitted in a form of ionizing radiation. The act of transformation is termed decay and the nucleus that changes and emits radiation is called a radionuclide. Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting ionizing particles and radiation. This decay, or loss of energy, results in an atom of one type, called the parent nuclide transforming to an atom of a different type, called the daughter nuclide.

For instance, the radioactive elements such as uranium are generally unstable and their nuclei can disintegrate or decay via the emission of alpha, beta and gamma radiations, thus releasing energy in the form of radiation and the nucleus can be transferred into another nucleus (Shapiro, 2002; Mann et al., 1980).

Environmental radioactivity is generally produced either naturally or artificially. Thus, Natural Occurring Radioactive Materials (NORM) has two origins: terrestrial and extraterrestrial origin. The terrestrial radioactivity is emitted from radio-nuclides that constitute a part of the composition of the earth's crust (Florou and Kritidis, 1992). There are three natural radio-nuclides series and one artificial. The three natural basic radioactive series are: the uranium-238 (^{238}U) series, the thorium-232 (^{232}Th) series and the actinium (^{235}U) series shown in Figures 1.2, 1.3, and 1.4. Each of these series ends with a stable nucleus of lead, but they also pass through radio-nuclides of other familiar elements.

Figure 1.2 shows the decay series of ^{238}U ending in the stable nuclide lead-206; it passes through the radionuclide radon-222, which is of special significance in radiological protection. The thorium series ending in the stable nuclide lead-208 and the actinium series ending in the stable nuclide lead-207.

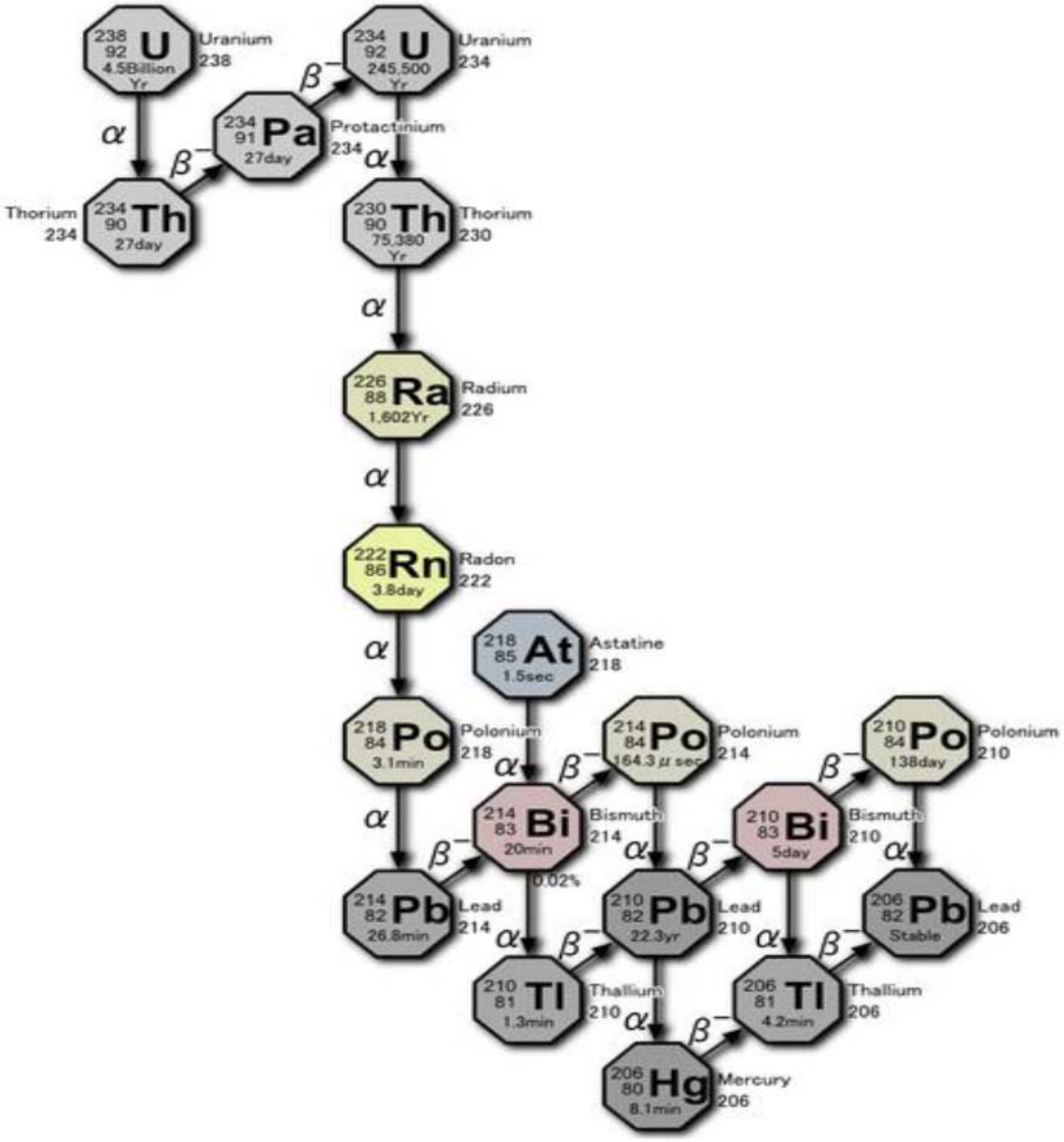


Fig. 1.2: A schematic diagram of the uranium series.
(http://en.wikipedia.org/wiki/Decay_chain, 9/4/2012)

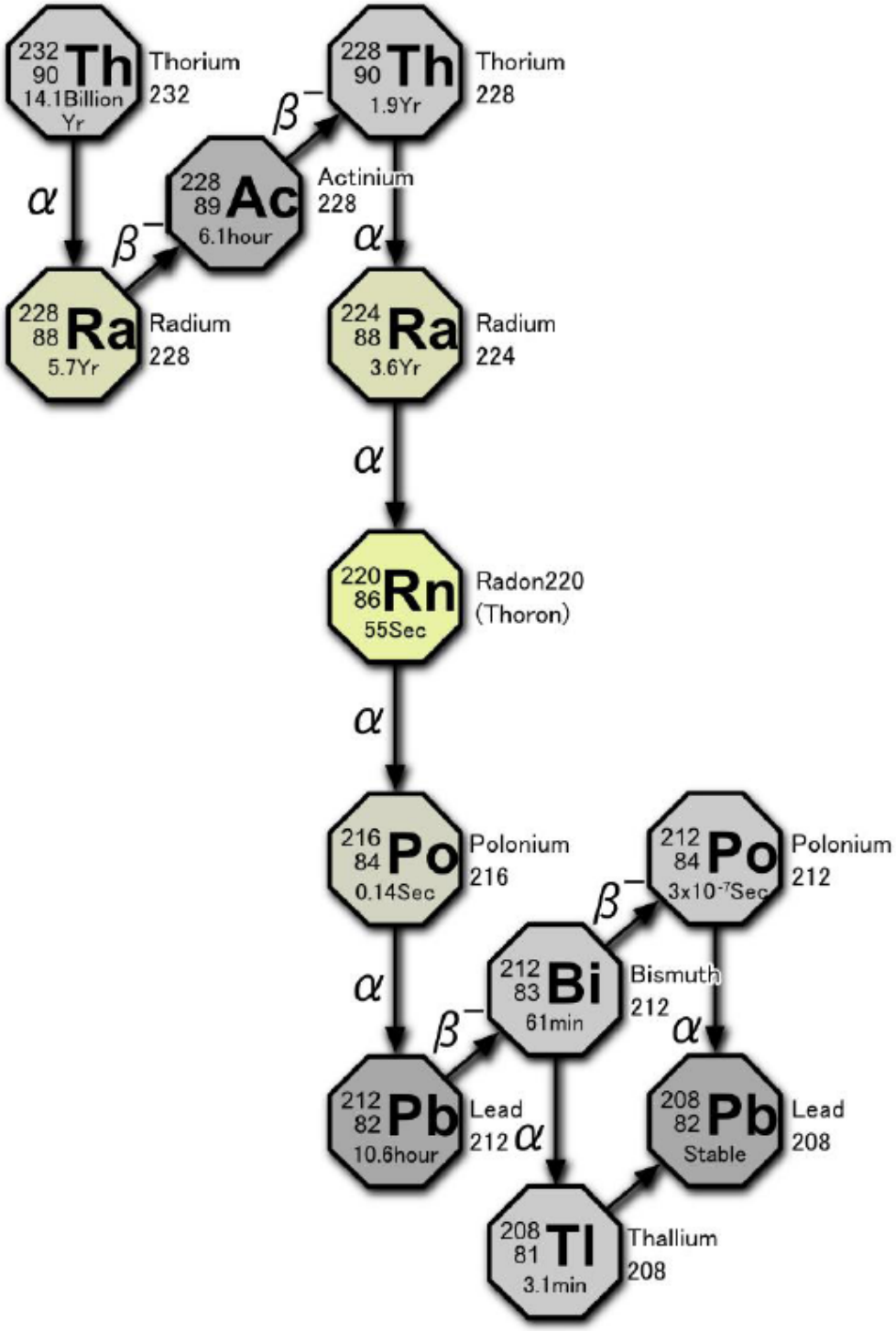


Fig. 1.3: A schematic diagram of the Thorium series .

(http://en.wikipedia.org/wiki/Decay_chain, 9/4/2012)

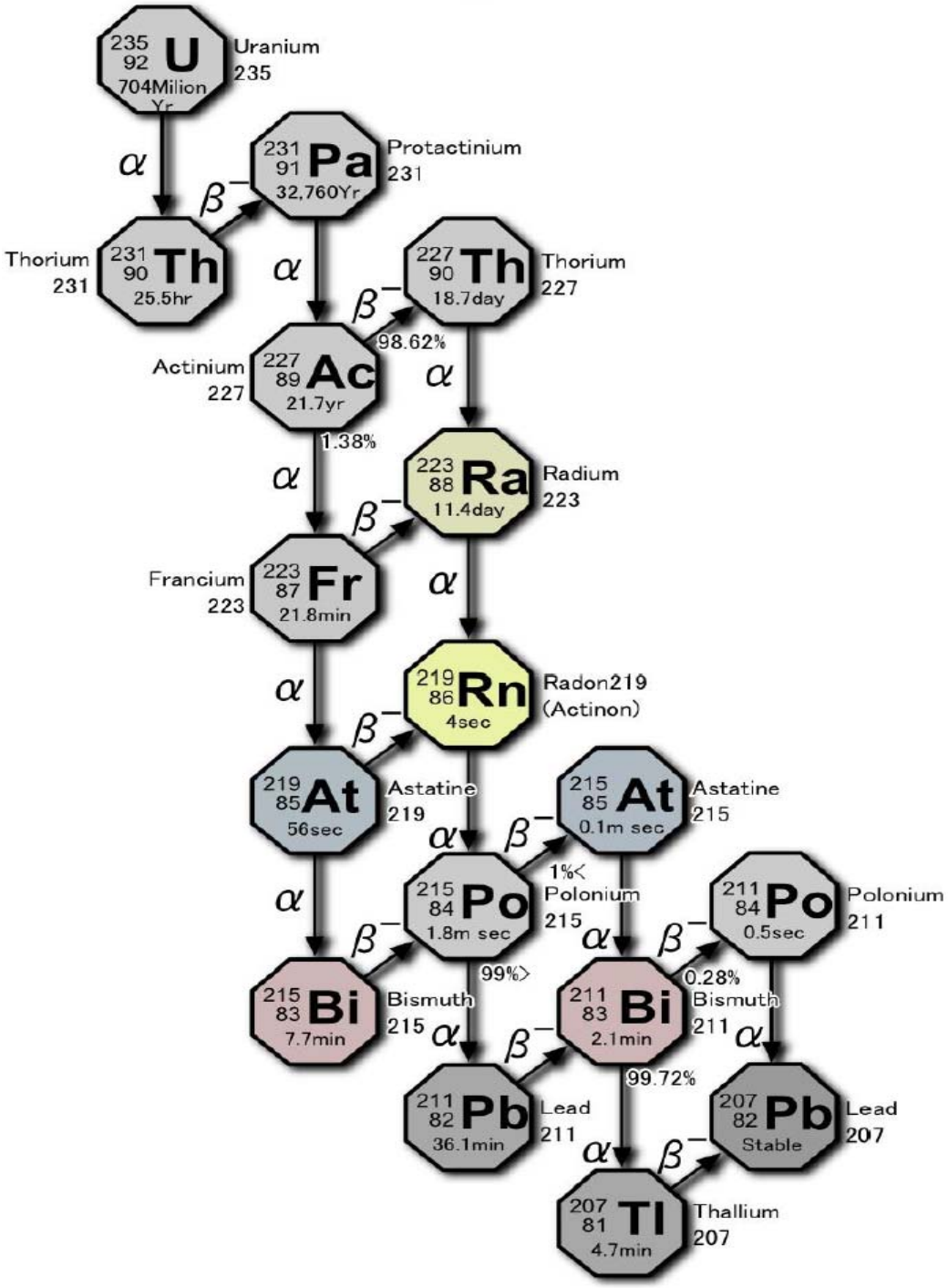


Fig. 1.4: A schematic diagram of the ^{235}U series (actinium) .

(http://en.wikipedia.org/wiki/Decay_chain, 9/4/2012)

1.2.1 The half-life

The radioactive half-life for a given radioisotope is the time for half the radioactive nuclide in any sample to undergo radioactive decay. After one half-life, there will be one half the activity of the original sample. After two half-lives, there will be one fourth the activity of the original sample, after three half-lives one eighth the activity of the original sample, and so forth.

1.2.2 Activity

The rate at which spontaneous transformation occur in a given amount of a radioactive material is known as the activity. Activity is expressed in a unit called Becquerel, symbol-Bq, where 1 Bq equals one transformation per second. The Becquerel is so small, multiples of the Becquerel are frequently used, such as megabequerel, MBq, which is 1 million Becquerel's. One gram of radium-226, for instance, has an activity of approximately 37000 MBq: it emits about 37000 million alpha particles each second. An old unit of activity, the Curie-named after the Polish-born French scientist Marie Curie-was originally defined as the activity of one gram of radium, i.e., 1 Curie is equal to 3.7×10^{10} decay/s.

1.2.3 Radiation Energy

The energy of the various types of ionized radiation-alpha and beta particles and gamma rays-is usually expressed in the unit of electron volt, symbol, eV. Multiples of this unit are often used, such as million or 10^6 electron volt, symbol MeV. For instance the energy of the alpha particles emitted by polonium-214 is about 7.7 MeV. Beta particles from lead-214, also formed in the uranium-238 decay series, have a maximum energy 1.0 MeV, and gamma rays produced by it have energies up to 0.35 MeV.

A most important property of the various types of ionizing radiation is their ability to penetrate matter. The depth of penetration for a particular type of radiation increases with its energy, but varies from one type to another for the same amount of energy. With charged particles such as alpha and beta particles, the depth of penetration also depends on the mass of the particle and its charge. For equal energies, a beta particle will penetrate to a much greater depth than an alpha particle.

Alpha particles can scarcely penetrate the dead, outer layer of human skin; consequently, radio-nuclides that emit them are not hazardous unless they are taken into the body through the breathing or eating or through a skin wound. Beta particles penetrate about a centimetre of tissue, so radio-nuclides that emit them are hazardous to superficial tissues, but not to internal organs unless they too are taken into the body. For indirectly ionizing radiation, such as gamma rays and neutrons, the degree of penetration depends on the nature of their interactions with tissue. Gamma rays can pass through the body, so radio-nuclides that emit them may be hazardous whether on the outside or inside. X-rays and neutrons can also pass through the body.

1.3 Radiation Exposure, Dose and Quantity

We can not detect ionizing radiation directly through our senses, but we can detect and measure it by other means: these include established methods based on photographic films, Geiger-Muller tubes, and Scintillation counters, as well as newer techniques using thermo-lumines materials and silicon diodes. We can interpret the measurements we make in terms of the energy that the radiation concerned would have deposited throughout the human body or in a particular part of the body.

Exposure is an index of the ability of a radiation field to ionize air, thus *exposure* refers to the amount of ionization produced in air by x- or gamma rays. The ionizing effects of radiation are measured by units of exposure. The coulomb per kilogram (C/kg) is the SI unit of ionizing radiation exposure, and measures the amount of radiation required to create 1 coulomb of charge of each polarity in 1 kilogram of matter. The older unit of exposure is called the roentgen (R), which represents the amount of gamma or x-rays radiation required to liberate 1 of charge of each polarity in 1 cubic centimetre of dry air. 1 Roentgen = 2.58×10^{-4} C/kg.

The amount of energy that ionizing radiation deposits in a unit mass of matter from any kind, such as human tissue, is called the absorbed dose (D). The (SI) unit of is gray (Gy). Where 1 Gy = 1J/kg and in rads (1Gy =100 rad) whereas one rad equals to the dose delivered to an object of 100 ergs of energy per gram of material.

An important quantity for radiation protection purposes is the equivalent dose (H) which is the product of the absorbed dose and a modifying factor called the radiation weighting factor (W_R). It accounts for differences in the relative biological effectiveness of different types of ionizing radiation doses. Various types of radiation might not produce the same biological effects, even when the energy delivered to the tissue is the same. Some values of radiation weighting factors are listed in Table 1.1.

Table1.1: Radiation weighting factors (W_R) of various particles

(http://www.euronuclear.org/info/encyclopedia/r/radiation-weight-factor.htm, 14/4/2012)

Type of radiation	Energy range	W_R
Photons, electrons, muons, beats	All energies	1
Thermal Neutrons	<10 keV, >20 MeV	5 5

Protons	>2 MeV	
Neutrons	10-100 keV, >2-20 MeV	10
Fast Neutrons Alpha particles, fission fragments, heavy nuclei	>0.1-2 MeV All energies	20 20

The radiation weighting factor for gamma rays, X rays, and beta particles is set at 1, so the absorbed dose and equivalent dose are numerically equal. For alpha particle, the factor is set at 20, so that the equivalent dose is deemed to be 20 times the absorbed dose. Values of the radiation weighting factor for neutrons of various energies range from 5 to 20.

The unit of equivalent dose (H) is the sievert (Sv); 1 Sv = 1 J/kg=100 rem; where rem is the former unit of equivalent dose and it stands for roentgen equivalent man. Submultiples of the Sv such as one-thousandth of a sievert (millisievert or mSv), or one-millionth of a sievert (microsievert or μSv), are generally used much in the way units of meters are used to describe distance.

Since all parts of the body and organs are not equally sensitive to the possible adverse effects of radiation, such as cancer induction and mutations. There is a useful radiation quantity which is called effective dose (H_{eff}) that used to express the relative risk to human. This quantity was introduced by ICRU in 1977. The ICRU defines the effective dose as the sum of all tissue equivalent doses multiplied by the appropriate tissue weighting factors (W_T) associated with each respective tissue. Some values of these factors are reported in Table 1.2. The SI unit of effective dose of radiation is sievert and the old unit is rem (roentgen equivalent in man). Where is 1 Sv = 100 rem.

There are many sources of ionizing radiation to which the population is exposed as shown in Fig 1.1.

Table 1.2: Tissue weighting factors (UNSCEAR, 2000).

Tissue of organ	W_T
Gonads	0.2
Bone marrow (red) Colon Lung Stomach	0.12
Bladder Liver Esophagus Thyroid Breast	0.05
Skin Bone surface	0.01
Remainder	0.05

1.4 External Exposure

External exposures outdoors arise from terrestrial radio-nuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks (UNSCEAR, 2000). There are exceptions, however, as some shales and phosphate rocks have relatively high content of radio-nuclides. There have been many surveys to determine the background levels of radio-nuclides in soils, which can in turn be related to the absorbed dose rates in air.

The activity concentration of ^{40}K in soil is an order of magnitude higher than that of ^{238}U and ^{232}Th. The maximum permissible worldwide values of the concentrations of these radio-nuclides in soil are reported in (UNSCEAR, 2000)Report, the Committee reported median values of 400, 35, and 30 Bq kg^{-1} for ^{40}K, $^{238}U$and ^{232}Th, respectively.

1.5 Radiation and Health

Naturally occurring radioactive materials (NORM) present in the earth's crust, the floors and walls of our homes, schools, or offices and in the food we eat and drink are the major contributor to the external dose of the world population (NCRP,1987). So this led the

scientists to study the environmental radioactivity in order to know the extent of its impact on human health and environment.

When radiation passes through matter, it deposits energy in the material concerned. Alpha and beta particles, being electrically charged, deposit energy through electrical interactions with electrons in the material. Gamma rays and X rays lose energy in a variety of ways, but each involves liberating atomic (orbiting) electrons, which then deposit in interactions with other electrons. Neutrons also lose energy in various ways, the most important being through collisions with nuclei that contain protons. The protons are then set into motion and, being charged, they again deposit energy through electrical interactions. So in all cases, the radiation ultimately produces electrical interactions in the material.

Each time a charged particle ionizes or excites an atom, it loses energy until it no longer has enough energy to interact; the final result of these energy losses is a minute rise in the temperature of the material of which the atoms is a part. In this way, all the energy deposited in biological tissues by ionizing radiation is eventually dissipated as heat through increased vibrations of the atomic and molecular structures. It is the initial ionization and the resulting chemical changes that cause harmful biological effects.

Ionizing radiation affects health when it causes changes in the cells of the human body. It does this by breaking the chemical bonds that hold together groups of atoms called molecules. When ionizing radiation passes through cellular tissue, it produces charged water molecule. This break up into entities called free radicals, such as the free hydroxyl radical (OH), which is composed of an oxygen atom and a hydrogen atom. Free radicals are highly reactive chemically and can alter important molecules in the cell.

One particularly important molecule is deoxyribonucleic acid, DNA, found mainly in the nucleus of the cell and contains a person's genetic information; control the chemical and physical functions of human cells. If DNA molecules are damaged the ability of the cells to do their work and to pass information to new cells is affected. We still do not fully understand all the ways in which radiation damages cells, but many involve changes to the DNA. There are two ways in which this can happen. Radiation may ionize a DNA molecule leading directly to a chemical change, or the DNA may be changed indirectly when it interacts with a free hydroxyl radical produced in the water of the cell by radiation. In either case, the chemical change can cause a harmful biological effect leading to the development of cancers or inherited genetic defects.

Radiation damages cells and DNA. All ionizing radiation damages cells. There is no level of exposure below which changes to a cell do not occur. Some of this damage can be repaired. Some will result in cancer. Studies of groups of people exposed to ionizing radiation have conclusively found that sufficiently large radiation doses can cause breast cancer (UNSCEAR, 2000). The probable health effects resulting from exposure to ionizing radiation are summarized in Table 1.3.

Table 1.3: Probable health effects resulting from exposure to ionizing radiation (Payne, 2006).

Dose in Rems (whole body)	Health effects immediate	Delayed
1000 or more	Immediate death. `Frying of the brain'.	None
600-1,000	Weakness, nausea, vomiting and diarrhea followed by apparent improvement. After several days: fever, diarrhea, blood discharge from the bowels, haemorrhage of the larynx, trachea, bronchi or lungs, vomiting of blood and blood in the urine.	Death in about 10 days. Autopsy shows destruction of haematopoietic tissues, including bone marrow, lymph nodes and spleen; swelling and degeneration of Epithelial cells of the intestines, genital organs and endocrine glands.
250-600	Nausea, vomiting, diarrhea, epilation (loss of hair), weakness, malaise, vomiting of blood, bloody discharge from the bowels or kidneys, nose bleeding, bleeding from gums and genitals, subcutaneous bleeding, fever, inflammation of the pharynx and stomach, and menstrual abnormalities. Marked destruction of bone marrow, lymph nodes and spleen causes decrease in blood cells especially granulocytes and thrombocytes.	Radiation-induced atrophy of the endocrine glands including the pituitary, thyroid and adrenal glands. From the third to fifth week after exposure, death is closely correlated with degree of leukocytopenia. More than 50% die in this time period. Survivors experience keloids, ophthalmological disorders, blood dyscrasias, malignant tumours, and psycho neurological disturbances.
150-250	Nausea and vomiting on the first day. Diarrhea and probable skin burns. Apparent improvement for about two weeks thereafter. Fatal or embryonic death if pregnant.	Symptoms of malaise as indicated above. Persons in poor health prior to exposure, or those who develop a serious infection, may not survive. The healthy adult recovers to somewhat normal health in about three months. He or she may have permanent health damage, may develop cancer or benign tumours, and will probably have a shortened lifespan. Genetic and teratogenic effects.
50-150	Acute radiation sickness and burns are less severe than at the higher exposure dose. Spontaneous abortion or stillbirth.	Tissue damage effects are less severe. Reduction in lymphocytes and neutrophils leaves the individual temporarily very vulnerable to infection. There may be genetic damage to offspring, benign or malignant tumours, premature aging and shortened lifespan. Genetic and teratogenic effects.
10-50	Most persons experience little or no immediate reaction. Sensitive individuals may experience radiation sickness.	Transient effects in lymphocytes and neutrophils. Premature aging, genetic effects and some risk of tumours.
0-10	None	Premature aging, mild mutations in offspring, some risk of excess tumours. Genetic and teratogenic effects.

1.6 Study Motivations and Objectives

The components of our environment such as soil , water and rocks contain radio-nuclides . The fact that concentration of radio-nuclides above the permissible global levels will be considered as a pollutant to our environment and it has a harm effect on our daily life attracts the scientists all over the world to this type of research. A tremendous investigation was performed worldwide.

In Palestine, a few studies have been performed on this topic. So, more research on natural radioactivity in Palestinian environment is required. Thus, it is important to identify the radioactive concentrations in soil because it is constitute a path for radioactivity to humans, animals and plants. And it is an indicator of radioactive accumulation in environment. This will shed light on the radio-nuclides concentrations in our local environment and will help us to judge whether our environment is polluted or not.

The present study is aimed on evaluation the activity concentrations of radio-nuclides in some soil samples collected from different locations in Bethlehem governorate during the spring season of 2011. The measurements are so important in assessing the external as well as internal radiation doses received by humans in these territories. The major objectives of the study are:

1. Measuring the activity concentrations and assessment of the radiological effects of naturally occurring radio-nuclides such as ^{238}U, ^{232Th} and ^{40}K and the important artificial radionuclide ^{137}Cs in soil samples using gamma ray spectrometry.

2. Establishing a data baseline to the radioactivity study for the area under investigation (Bethlehem region – Palestine) that has not been investigated before. The baseline map will be used as a reference information to assess any further changes in the radioactivity background levels due to various geological processes or artificial influences around the area under considerations.

1.7 Previous studies in Palestine

Few studies on natural radioactivity concentration measurements are reported. Here are some of the well known studies conducted in the West Bank, Palestine.

1. The measuring of the natural radioactivity levels in geological rocks from Hebron province (Abu-Samreh, 2006).
2. The assessment of the natural and man-made radioactivity levels was performed in plant leaves samples from Hebron province, Palestine (El-Shershaby et al., 2006).
3. The measuring of radioactivity levels in different types of fabricated building materials used in Palestine (Dabayneh,2007).
4. The measurement of natural and man made radioactivity in soil samples at Hebron region (Dabayneh et al.,2008).
5. The measurement of natural radioactivity in different commercial ceramic samples used in Palestinian buildings as construction materials (Dabayneh,2008)..
6. The study that was made by Dabayneh in soil samples in the southern part of the West Bank , Palestine (Dabayneh et al., 2008).
7. The work presented qualitative and quantitative evaluation of environmental radioactivity in the central and southern areas of the West Bank, Palestine was conducted by (Lahham et al., 2009).

8. The estimation of activity concentrations of radio-nuclides ^{226}Ra, ^{232}Th and ^{40}K and manmade radionuclide ^{137}Cs in soil samples collected from Tulkarem province-West Bank-Palestine (Thabayneh and Jazzar, 2012) .

Chapter Two

Experimental Techniques

Chapter Two
Experimental Techniques

2.1 Introduction

In this Chapter, we shall discuss several practical and experimental aspects such as sample collection, preparation, experimental setup, energy calibration and efficiency calibration of the detector and samples analysis. Besides, we shall shed light on the high-purity germanium detector used in this study.

2.2 The site

Bethlehem Governorate is located in the southern part of the West Bank, 6 kilometres south of Jerusalem as shown in Fig.2.1. It lies between Hebron and Jerusalem governorates at the confluence of latitude 31.42º north, and longitude 35.12º east. It extends to two hills, the highest of them up to 750m above sea level , and it is a part of the central mountains and hills in Palestine that spread parallel to the Jordan Valley and Dead Sea. It extends on a total area of 659 km^2 and its total population is about 188,880 in 2010 (Palestinian Central Bureau of Statistics, 2010). The governorate is divided into 10 cities, 25 villages and camps

(http://ar.wikipedia.org/wiki/%D8%A8%D9%8A%D8%AA_%D9%84%D8%AD%D9%85)

In this study, soil samples were collected from several positions as described in Appendix A and locations in villages to be chosen randomly from villages and cites scattered throughout the governorate.

2.3 Soil Samples collection

In 2011, a total of 50 soil samples were collected randomly from 24 arbitrary positions located in Bethlehem governorate and exhibited in Fig. 2.2. The method of collection can be summarized as follows: All extraneous materials such as, glass pieces, twigs, stones, or leaves that might cause an error in the analytical results, were removed from the soil surface before collecting the soil sample.

A soil sample of 1.5 to 2 kg was collected from the soil chosen site at a depth ranges from 5 cm to 30 cm using stainless steel shovel and a stainless steel template 25 cm by 25 cm in area and 8 cm in depth. The distances between one collecting site and another for all samples are ranged from 2 km to 5 km.

Fig.2.1: Map of provinces and cities in the West Bank, Palestine, Palestine.

(http://looklex.com/e.o/map_westbank.htm, 3/5/2012)

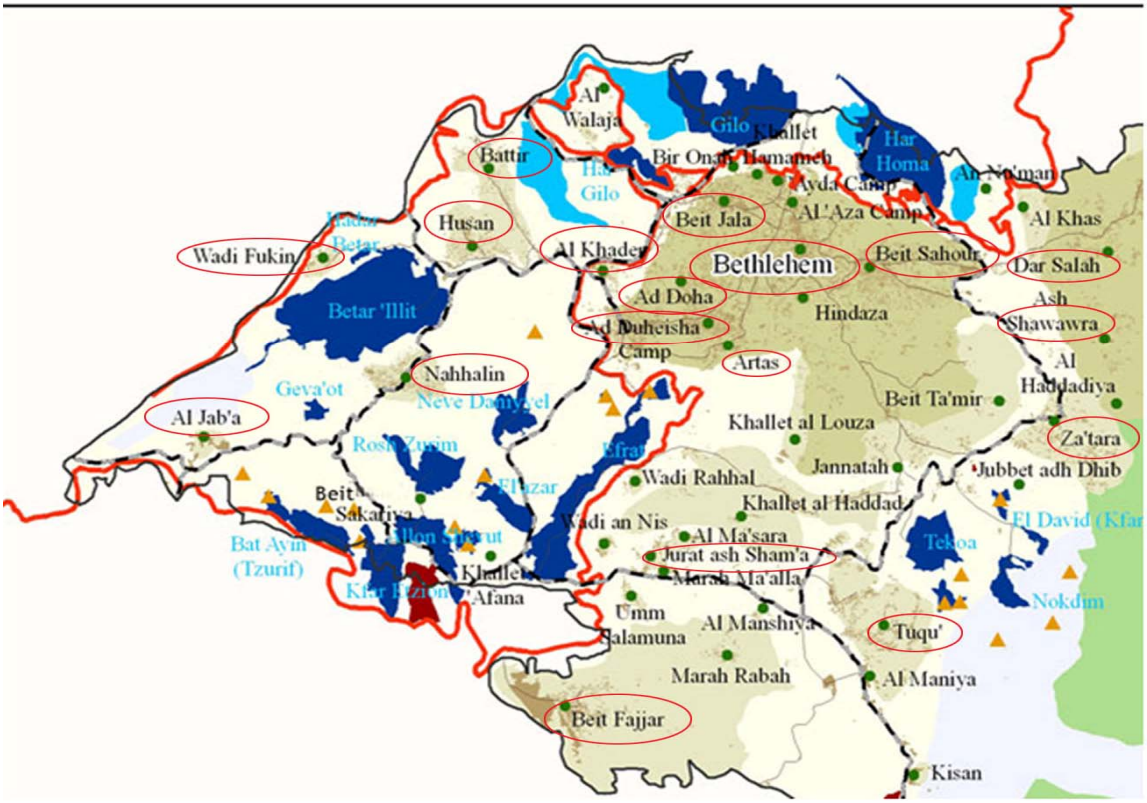


Fig. 2.2: Map of Bethlehem governorate showing the locations of the cities and villages under investigation (http://vprofile.arij.org/Bethlehem, 14/8/2011).

The collected soil materials were divided into samples, where each was filled into labelled polyethylene bag of volume four litters and sealed by scotch tape as shown in Fig. 2.3.

Fig. 2.3: The labelled polyethylene bags filled with soil material.

Each sample is coded and relevant information such as the sample site, land properties of the site (cultivated or uncultivated), type of crops in cultivated lands, the sampling date, the depth level, the type of terrain at this site, the sample type and the sample code are recorded separately in prepared labels and stuck with a waterproof tape on each sample bag. The filled bags were shipped to the laboratory of radioactive contamination at Hebron University-Palestine for standardisation before inspection and data analysis.

2.4 Soil samples preparation

Prior to the final measurements in the laboratory at Hebron University, the samples were dried in an oven at 110ºC for 48 hours to remove the moisture completely. The samples then were sieved through 0.5 mm mesh sieve to obtain uniform particle size. samples are prepared according to the general methods used in this type of research, where soil material is placed in one litter plastic Marinelli beaker with 87 mm bore diameter as shown in Fig. 2.4, and weighed using an electronic balance as shown in Fig. 2.5. The mass of each soil sample is listed in Table 2.1.

Fig. 2.4: (a) Empty standard Marinelli beakers.

Fig. 2.4: (b) Prepared soil samples filled in standard Marinelli beakers.

Fig.2.5: The electronic balance used in weighing soil samples.

Table 2.1: The masses of soil samples.

Sample code	Mass of sample (g)	Sample code	Mass of sample (g)
BS1	1005.8	BS26	975.2
BS2	1380.8	BS27	1282.1
BS3	970	BS28	1100
BS4	1062.4	BS29	1220.2
BS5	1132.4	BS30	1093.1
BS6	1060	BS31	1130.1
BS7	1224.5	BS32	1217.7
BS8	1236.9	BS33	1381

BS9	1075.9	BS34	863.3
BS10	1296	BS35	795.6
BS11	1214.6	BS36	1318.3
BS12	1018.2	BS37	881.6
BS13	1122.9	BS38	1226.7
BS14	1001.5	BS39	1404.3
BS15	1198.2	BS40	1313.5
BS16	1258.8	BS41	1096.1
BS17	1230.4	BS42	1032.3
BS18	1210.5	BS43	1305.1
BS19	1292.3	BS44	1100.2
BS20	1363.2	BS45	1061.2
BS21	1199.7	BS46	1172.6
BS22	1025.8	BS47	1300.8
BS23	1306.7	BS48	1242.2
BS24	1262.3	BS49	1212.3
BS25	1093.1	BS50	891.8

Finally, the samples were stored and kept sealed for about four weeks to allow time for ^{238}U and ^{232}Th to reach secular equilibrium with their daughter nuclei (Al- Jundi et al.,2003). After the isolation period, each sample was analyzed using gamma ray (γ-ray) spectrometry. This will be discussed in the following section.

2.5 Experimental setup

Measurement of radioactivity concentrations of the collected soil samples is conducted by using the γ-ray spectrometry. This is a powerful technique for estimating qualitative and quantitative low level natural and anthropogenic radioactivity in environmental samples through their γ- ray emission. The experimental setup is shown in Fig.2.6. The setup is composed mainly from γ- rays' spectrometer and a personnel computer, PC, unit to store and analyze data. Extensive discussion of the γ-rays spectrometer will be discussed in the following subsections.

Fig. 2.6: A general view of the HPGe γ-ray spectrometer.

2.5.1 The γ- ray spectrometer

The γ- ray spectrometer used in this study consists of:

2.5.1.1. A Hyper Purity Germanium coaxial Detector (HPGe)

A hyper purity germanium coaxial detector (Ortec Model GMX15P4 with serial number 45-TN22006C) operate at 2.5 kV negative bias with an efficiency of 15%, relative to that of a standard 7.62 cm × 7.62 cm cylindrical NaI(T1) scintillation crystal and is normally based on the measurement of the 1330 keV gamma ray photo peak of a ^{60}Co source with a source detector spacing of 25 cm used in both measurement systems.

The energy resolution of the detector, which is specified as the full width at half maximum (FWHM) of the full energy peak of the 1332.5 keV peak of ^{60}Co is equal to 1.85 keV. The detector has a coaxial cylindrical shape of 45.5 mm in diameter and 60.2 mm in length with 3 mm end cap to detector. The detector converts the incident γ- ray energies deposited in it into electrical pulses.

2.5.1.2. Detector Cryostat and Dewar (DCD)

As germanium has a small band energy gap of 0.7 eV, so a large thermally leakage current will be resulted in germanium crystal at room temperature. Accordingly, HPGe detector can not operate at room temperature. To avoid this problem, HPGe detector should be cooled to 77 K (temperature of liquid nitrogen) in order to reduce the leakage current that may spoil the energy resolution of the detector. For this purpose, the cryostat and dewar were used. As shown in Fig. 2.7 the cryostat has a vertical configuration consists of a vacuum chamber, which hosts the detector element to avoid thermal conductivity between the germanium crystal and the surrounding air and the detector cryostat is equipped with a beryllium window of 0.5 mm thick covered by plastic cover located at the front face of the detector to allow photons of energy down to 3 keV to enter the active volume of the detector. And the mounted detector on the cryostat is dipped into a thirty litter dewar filled with liquid nitrogen to reduce the temperature of the germanium crystal to 77 K (Knoll, 2000) as shown in Fig. 2.8.

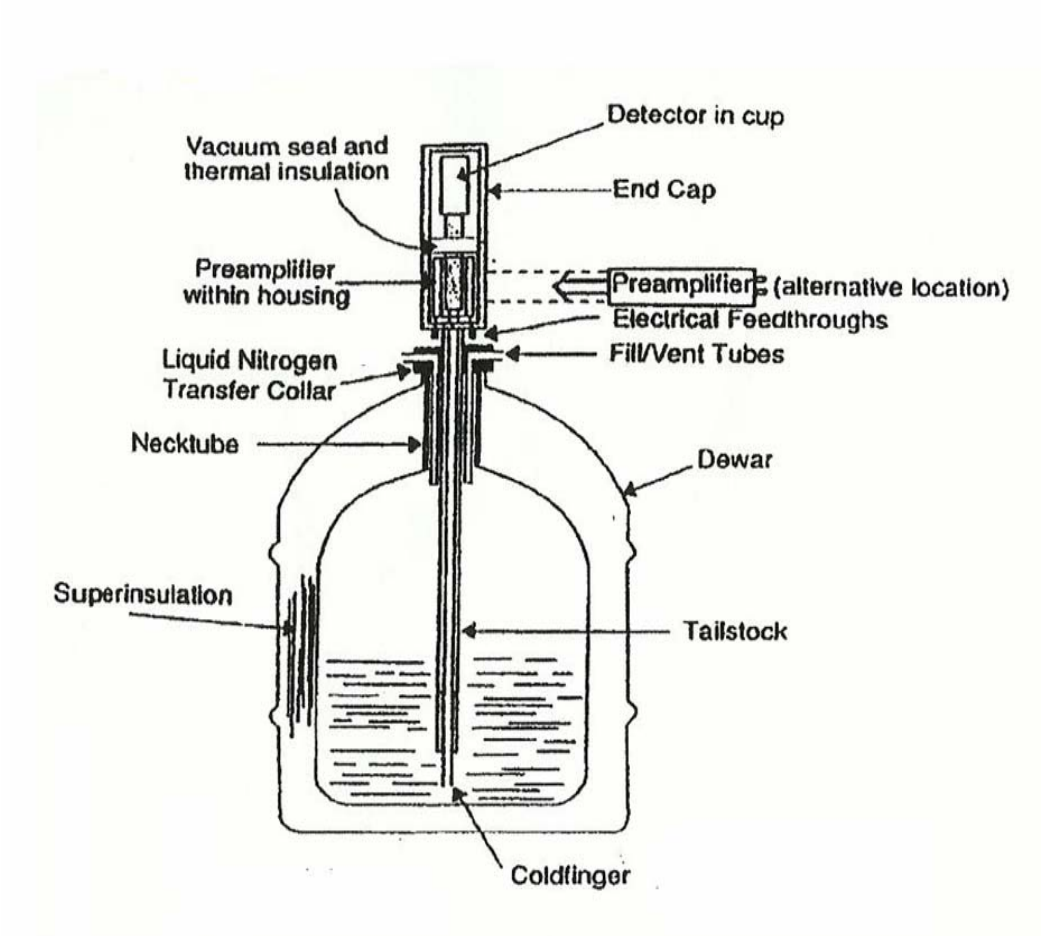
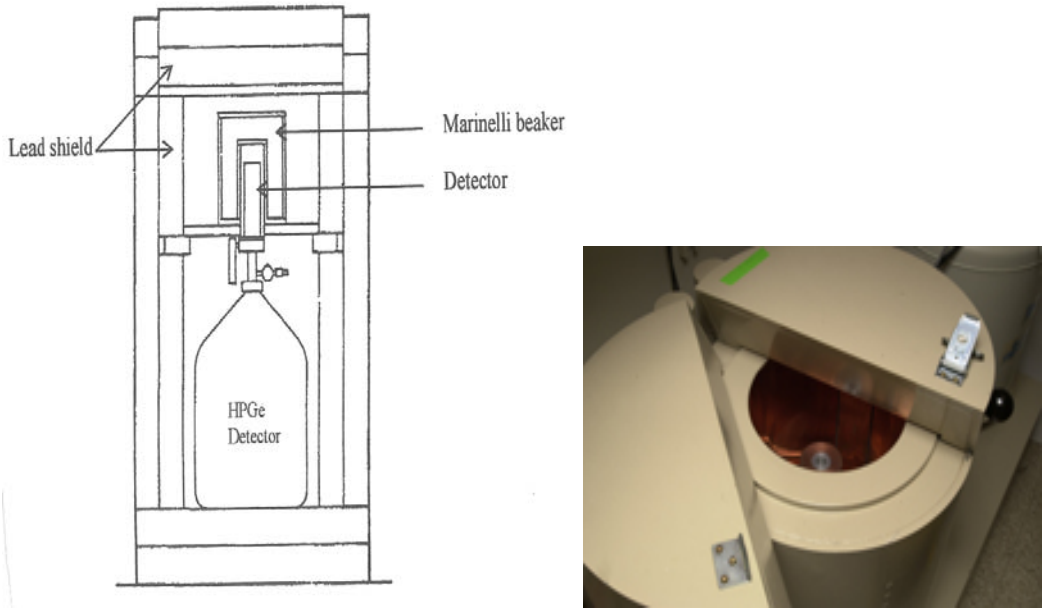


Fig.2.7: Schematic diagram for an HPGe detector.

Fig.2.8: Filling of liquid nitrogen.

2.5.1.3. Detector shielding

To reduce the γ- radiation background present at the laboratory site, the detector was shielded in a 10 cm thick of cylindrical lead shield internally lined with 2 mm copper foil (Al- Jundi et al.,2003) with a fixed bottom and movable cover as shown in Fig. 2.9.



(a) (b)

Fig. 2.9 : (a) Schematic diagram for a HPGe detector shielding, (b) A movable cover of a cylindrical lead shield.

2.5.1.4. Electronics

The electronic system for the standard HPGe detector is shown schematically in Fig.2.10.

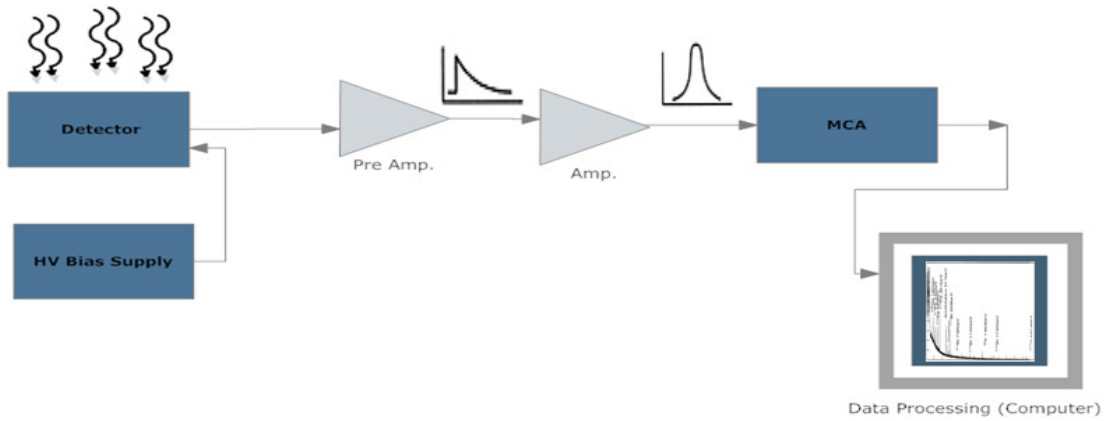


Fig. 2.10: A schematic diagram illustrating the electronic setup used to acquire the HPGe detector data. (Al-Sulaiti, 2011)

The electronic system consists of the following main components:

A) High voltage power supply (model 659)

equipped with a remote shut down feature, and signal processing electronics which is used to supply the detector with high voltage that is equal to 2.5 kV in this study. The signal processing electronics are clarified in the next subsections.

B) Preamplifier (model A257N)

The preamplifier is located between detector and amplifier. It converts the electronic signal comes from the detector to a voltage pulse. And then it amplifies this pulse to become with an amplitude of mill volts and gives the pulse a preliminary shape. Then it sends the pulse to the rest of equipment through cable. For best performance of the preamplifier, it must be placed as close as possible to the detector, and connected to the germanium crystal to reduce the length of cable (30 cm or less from the detector)

since the electrical signal is weak, so the input components are kept at liquid nitrogen temperature (Mann et al.,1980 ; Krane ,1988) .

C) Spectroscopic amplifier (model 572A)

The amplifier has two functions : Firstly, completes the amplification of the electronic pulse that comes from the preamplifier to become with an amplitude in range of a few volts which appropriate for subsequent pulse analysis. Secondly, converting the signal at the output of the preamplifier to a suitable shape for radiation measurements (Mann et al.,1980 ; Krane ,1988) .

D) Multi Channel Analyzer

After the amplification the electronic pulses are processed using a Multi Channel Buffer (MCB) which is a PC-based plug in Peripheral Component Interconnect (PCI) card consisting of an 8k analog-to-digital converter, ADC, and an advanced Multi Channel Analyzer, MCA, emulation software (MAYSTRO-32). An ADC is used to convert each pulse into a channel number, so that each channel corresponds to a narrow range of pulse heights or voltages. As pulses arrive over time, the MCA collects in memory a distribution of the number of pulses with respect to pulse height (a series of memory locations, corresponding to ADC channels, will contain the number of pulses of similar, although not necessarily identical, height). This distribution, arranged in order of ascending energies, is commonly referred to as a spectrum (Software user's manual. Software version 6.0. Ortec part No.777800.1206. Manual revision L).

2.6 Energy calibration of the HPGe detector

Energy calibration is a process in which the energy scale of the pulse height distribution is determined. In the other words, the radio-nuclides within a spectrum are identified by matching the energies of the principal γ- rays observed in the spectrum with the energies of the γ- rays emitted by known radio-nuclides (Harb, 2004). This process was performed before doing any data collection and analysis for each soil sample using standard γ- ray emitters having well known energies.

For accurate energy calibration of the HPGe detector system the correct energies must be assigned to the centroid of each full energy peak in a source emitting γ –rays of known energy spectrum (Harb, 2004). The energy calibration was done in this study by using standard sources with well known energies within the range of 59.5 keV to 1836 keV summarized in Table 2.2, which are not widely different from those to be measured in the unknown spectrum.

These standard sources were packed in one litter plastic Marenilli beaker having the same geometry as that used for samples measurements. The spectrum of these sources was measured for one hour to achieve accurate peaks that will be used for the calibration. The positions of the resulting observed full energy peaks were marked in the computer program and the corresponding energies that might be found in the centroid of each of them were recorded. Whereas the channel number that corresponds to the centroid of each fit energy photo peak on the MCA should be recorded and plotted on origin software program on the x-axis versus the gamma ray energy on the y-axis.

A linear curve will result in the plot slope and intercept of the energy calibration line should be determined by least squares calculations. Computerized systems are usually equipped to perform their slope and intercept calculations automatically during the calibration routine. So, the energy values can be evaluated after the determination of the limiting coefficients of the system used and its nonlinear components at each channel number using the following relation :

$$E(keV) = A_0 + A_1 N + A_2 N^2 + A_3 N^3 \qquad (2.1)$$

Where

E : is the energy of the photo peak

A_0: channel cut off

A_1 : coefficient showing the linearity of the spectrometer

A_2, A_3 : non linear coefficient components

N : channel number

Table 2.2: Gamma ray lines of various gamma standard sources used in energy calibration.

Radionuclide	**Energy(keV)**	**Channel number**
^{60}Co	1173.5	2443
	1332.5	2774
^{241}Am	59.5	122
^{226}Ra	186.2	385
	242	501
	295.2	611
	351.9	730
	609.3	1266
^{137}Cs	661.3	1375
^{88}Y	1836	3823

Fig. 2.11 represents the predicted linear relation between the gamma energy of the different standard sources and corresponding peak position channel number.

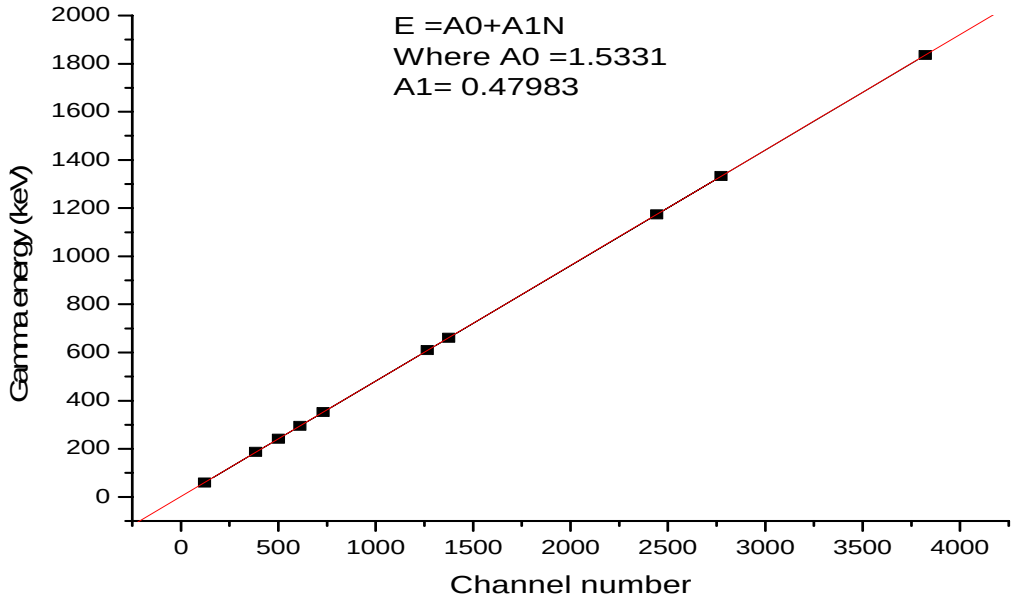


Fig.2.11: Energy channel calibration curve.

2.7 Efficiency calibration of the HPGe detector

The intrinsic detection efficiency of any device operated in pulse mode is defined as the probability that a quantum of radiation incident on the detector will produce a recorded pulse. Especially for radiations of low intensity, high detection efficiency is important to minimize the total time needed to record enough pulses for good statistical accuracy in the measurement.(http://www.britannica.com/EBchecked/topic/1357248/radiation measurement/80700/Detection-efficiency, 4/5/2012).

The efficiency calibration aims to derive a relationship between the absolute full energy peak efficiency of the gamma-ray spectroscopy system and the energy (Al-Sulaiti,2011). The relative efficiency calibration of the spectrometer was carried out using the following

standard sources: ^{241}Am (60 KeV), ^{109}Cd (88 KeV), ^{57}Co (122 KeV) ,^{60}Co (1173 and 1333 KeV), ^{139}Ce (166 KeV), ^{203}Hg (279 KeV), ^{113}Tin (392 KeV), ^{85}Sr (514 KeV) ^{137}Cs (662 KeV) and ^{88}Y (898 and 1836 KeV). The calibration efficiency curve beyond 1850 keV was constructed using different energy peaks of Ra-226 in order to cover the range from 60 to 2500 KeV. The standard source packed in one litter plastic Marinelli beaker has the same geometry as that used for measured samples. Absolute efficiency calibrations were calculated to study isotopes by using the last standard source and chemically pure KCl dissolved in distilled water at different concentrations. The absolute efficiency of the detector for each gamma ray energy was then calculated from the well known formula: (http://www.df.uba.ar/users/sgil/labo5_uba/recursos/Spectrum%20Analysis%20%20Canberra%20Industries.htm , 24/1/2012):

$$\varepsilon = \frac{Net\,Area(c/s)}{AI} \times 100\%, cps/Bq \qquad (2.2)$$

where ε is the photopeak absolute efficiency, Net Area represents the net counts per second (c/s) for the standard, A is the activity of the radio-nuclides in Bq, and I is the number of gamma rays per disintegration (Knoll, 2000).

The energy peaks and the calculated efficiencies from equation (2.2), for HPGe used detector in this study are plotted in Fig. 2.12 using the origin plotting program.

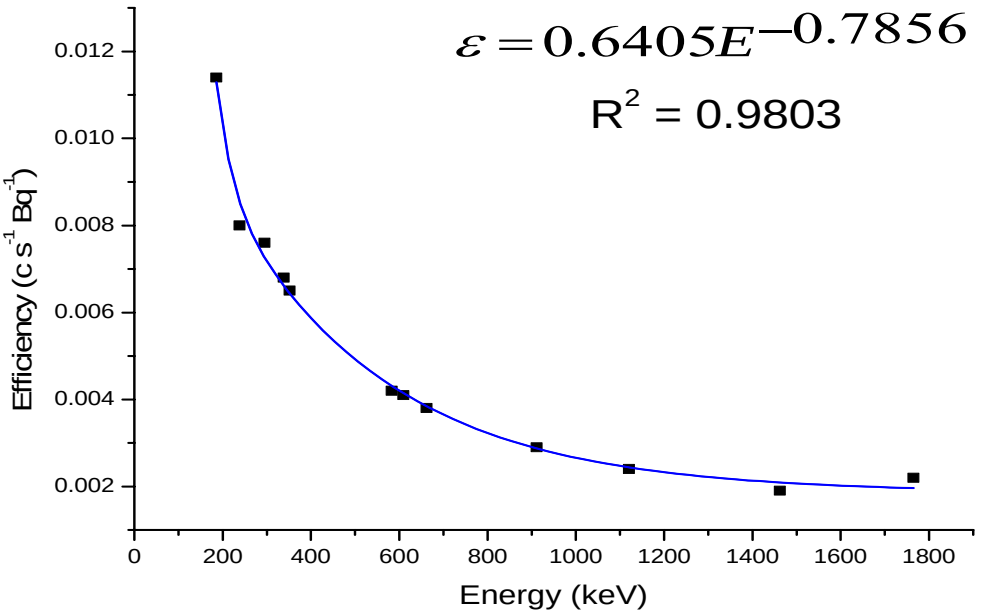


Fig. 2.12: The calibration curve of the efficiency for HPGe detector

As can be seen from Fig.2.12 and equation (2.2), the efficiency decreases by increasing energy. This is because the γ-rays of higher energies are difficult to be detected by the detector since they just pass through the active volume of the detector without creating electronic signals, or in other words the probability of interaction between photon and the detector decreases with increasing photon's energy (Knoll, 2000). It was found that the highest γ-rays detection efficiency is the one corresponding to γ- rays having low intensity and energy. The dependence of efficiency on energy is found to fit the following empirical formula :

$$\varepsilon = \frac{0.6405}{E^{0.7856}} \qquad (2.3)$$

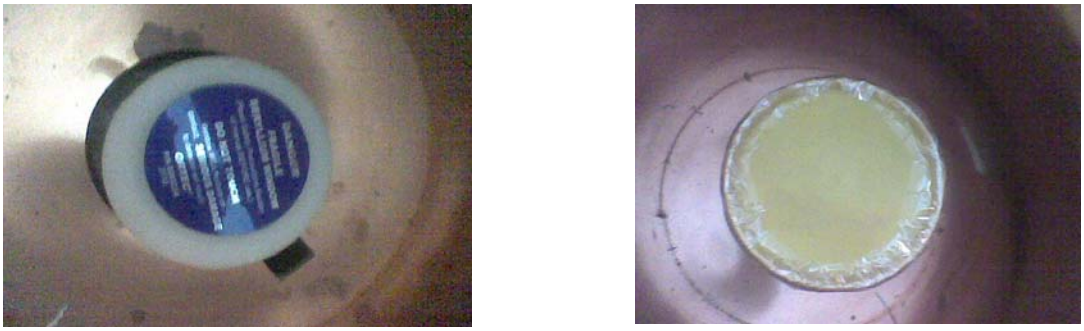
Whereas the correlation factor of the energy- efficiency data is 0.98.

2.8 Samples analysis

Before performing the measurements of radio-nuclides activity in the soil samples, the environmental gamma - background radiation at the laboratory site has to be determined.

This can be achieved by putting an empty one litter Marinelli beaker into the shielded HPGe detector and measuring radiation background (R.B.G.) for **70000 seconds**. The obtained R.B.G. should be later subtracted from the measured γ-ray spectra of each soil sample.

For radioactivity measurements, each sample was placed directly over the front face of the detector as shown in Fig. 2.13 below and measured for 70000 seconds. (A typical γ – ray spectrum is shown in Fig. 2.14).



(a) (b)

Fig. 2.13: (a) The HPGe detector, (b) The soil sample placed on the detector.

In the exhibited spectrum shown in Fig.2.13, all photons that interact with the detector material within the active volume of the detector are registered. Since radio-nuclides emit a discrete spectrum of photons that will interact with the active volume of the detector, the absorption of these photon energies within the active volume of the detector lead to the appearance of peaks in the spectrum at these photon energies.

After measurements were completed, the γ–ray spectrum was analyzed using (MAESTRO–32) software which performs a Gaussian fitting to the significant photo-peaks appearing in the spectrum. The software program allow the user to select the peaks regions in the spectrum exhibited on the display by using a cursor in order to calculate their areas automatically by the program, as it appears on the display a menu–driven report include

centroid channel, energy, net area counts, background counts, intensity and full width at half maximum (FWHM) of the selected peaks in the spectrum.

This general procedure will be used in obtaining the radio-nuclides activity concentrations in the collected soil samples from Bethlehem governorate. Details of all parameters calculations such as radium equivalent activity, outdoor air–absorbed dose rate, indoor air – absorbed dose rate, annual effective dose equivalent, external and internal hazard indices and radioactivity level index based on the obtained data result from the experimental measurements are presented in Chapter 3.

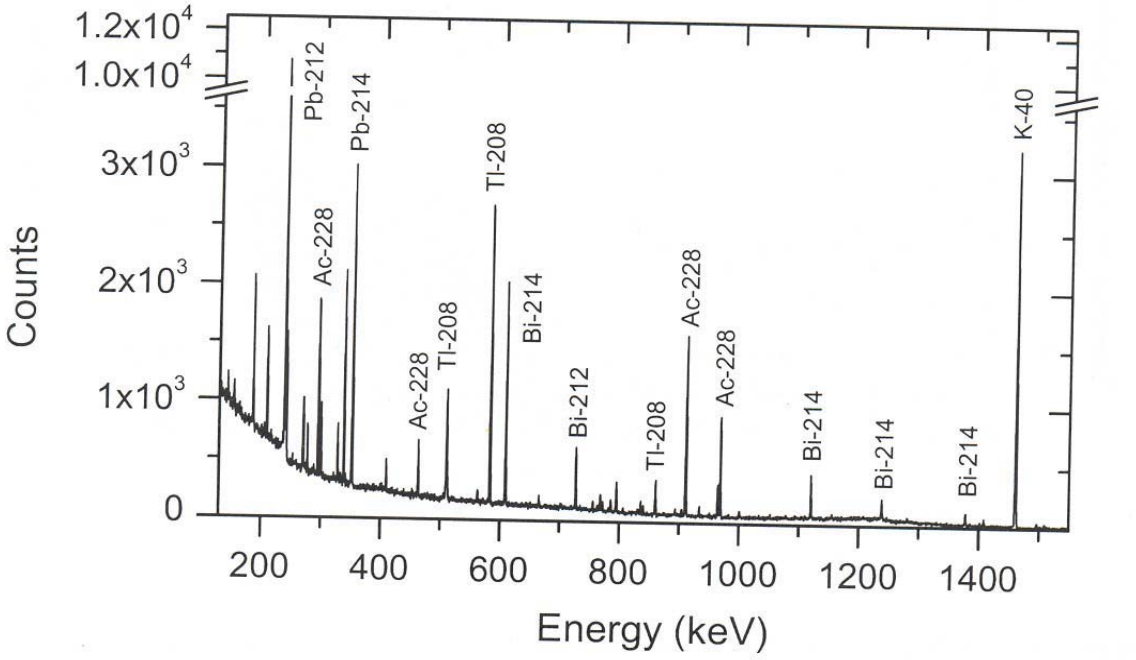


Fig. 2.14: Typical gamma – ray spectrum.

Chapter Three

Theoretical Calculations

Chapter Three
Theoretical Calculations

3.1 Introduction

In this Chapter, the activity concentration levels of natural radio-nuclides and man made radionuclide, ^{137}Cs, are calculated theoretically. Also, the radiological effect parameters are calculated theoretically for comparing the calculated values with the permissible worldwide values and to assess the levels of radiation risk in the investigated regions in the next Chapter.

3.2 The calculations of radioactivity concentration levels

Direct calculations of ^{238}U and ^{232}Th concentrations in soil samples without any chemical treatment using HPGe detector is very hard because they do not emit any intensive γ- rays (lines) of their own . But they have several progenies which have more intensive lines and activities equal to their parents in the state of secular equilibrium. Thus, the calculations of the concentrations of these radio-nuclides relied on the detecting emissions from their progenies by using HPGe detector (Kabir et al., 2009).

For the radionuclide which has more than one peak (such as ^{238}U and ^{232}Th due to their daughters) in the energy range of analysis , the peak activities are averaged and the result is the weighted average nuclide activity (Akhtar et al., 2004). So, the ^{238}U activity concentration was calculated from the mean value of six γ-ray lines obtained from the photo peaks of ^{226}Ra (186.2 keV), ^{214}Pb (295.2 keV ; 351.9keV) and ^{214}Bi(609.3keV ; 1120.3keV ; 1764.8keV). The ^{232}Th activity concentration was calculated from the mean value of four γ-ray lines obtained from the photo peaks of ^{212}Pb (238.6 keV), ^{228}Ac (338.5 keV ; 911.1 keV) and ^{208}Tl (583.1 keV). The ^{40}K and ^{137}Cs activities were

measured from their own γ-ray energies 1461.8 keV and 661.6 keV respectively (Huy and Luyen, 2005 ; Dabayneh et al. , 2008).

The program gives the count rates that are proportional to the number atoms that decayed in the sample during the time of measurement. the radioactivity concentrations in the soil samples were obtained using the following equation (Abbady et al. 2006; Abdel-Ghany, 2010; Thabayneh and Jazzar, 2012):

$$A_{Ei}(Bq/kg) = \frac{C}{\varepsilon \times I \times M} \qquad (3.1)$$

Where A_{Ei} is the activity concentration of a nuclide i and for a peak at energy E, C is the net gamma counting rate (counts per second for a peak at energy E), ε is the detection efficiency at energy E, I is the number of gamma rays per disintegration of this nuclide for a transition at energy E and M is the mass of the sample measured in kilograms.

The count rates after subtracting the background counts of the spectrum as shown in Fig. 3.1 are used to calculate automatically the net areas under the most prominent photo peaks of uranium and thorium daughters, potassium and Cesium that appear in the spectrum using MAESTRO – 32 software program. Then, the activity concentration of each radionuclide can be calculated from the background subtracted area of prominent photo peaks (Mahur et al., 2010).

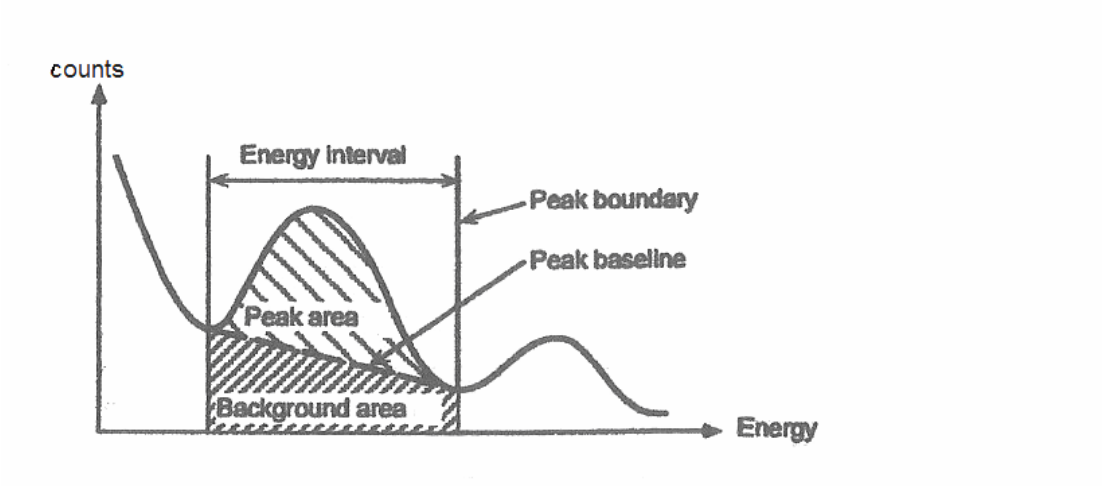


Fig. 3.1: Schematic diagram illustrating a MCA spectrum from HPGe detector.

The obtained activity concentrations are used to calculate the average activity concentrations of ^{238}U series,^{232}Th series,^{40}K and ^{137}Cs. In the following Chapter, these values will be compared with the worldwide values reported by (UNSCEAR, 2000).

3.3 The calculations of radiological effect parameters

3.3.1 Radium equivalent activity

Since the distribution of ^{238}U, ^{232}Th and ^{40}K in soil samples is not uniform, uniformity with respect to exposure to radiation can be defined in terms of radium equivalent activity (Ra_{eq}). The Ra_{eq} can be used to assess the health effects produced from the radioactivity of radio-nuclides in materials contain different amounts of ^{238}U, ^{232}Th and ^{40}K usually detected in the earth's crust. The radium equivalent activity is a weighted sum of activities of ^{238}U, ^{232}Th and ^{40}K based on the assumption that 370 Bq/ kg of ^{238}U, 259Bq/ kg of ^{232}Th and 4810 Bq/ kg of ^{40}K produce the same gamma-ray dose rate (Mahur, 2010). Accordingly, Ra_{eq} is calculated by using the following equation (Huy and Luyen, 2005; Ibrahim, 1999; Alharbi et al., 2011):

$$Ra_{eq}\,(Bq/kg) = A_U + 1.43 \times A_{Th} + 0.077 \times A_k \qquad (3.2)$$

where A_U, A_{Th} and A_K are the calculated average activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively. These activities are expressed and calculated using equation (3.1).

3.3.2 The outdoor air-absorbed dose rate

The outdoor -air absorbed dose rate**,** D_r **,** due to terrestrial γ-rays at 1m above the ground level, was calculated from the activity concentration values of ^{238}U, ^{238}Th and ^{40}K, using the semi-empirical formula (El-Shershaby et al., 2006; Chowdhury et al., 2005; Tzortzis et al., 2002):

$$D_r(nGy/h) = 0.427 \times A_U + 0.662 \times A_{Th} + 0.043 \times A_K \qquad (3.3)$$

where 0.427 , 0.662 and 0.043 are the dose rate conversion factors (absorbed dose rate in air per unit activity per unit of soil mass, in units of nGy h^{-1} per Bq kg^{-1}) proposed by (UNSCEAR, 1988) which transform the activity concentrations of ^{238}U , ^{232}Th and ^{40}K, respectively, into absorbed dose rate. These conversion factors were originally derived from Monte Carlo calculations using mathematical phantoms.
(http://nestoras.ee.auth.gr/publications/html/hps_78.html , 27/1/2012)

More recently, equation (3.3) is modified to include the contributions from artificial radio-nuclides ^{137}Cs as well as cosmic radiation according to the following equation (El-Shershaby et al., 2006; Dabayneh et al. 2008; Hilal, 2002):

$$D_\gamma(nGy/h) = 0.427 \times A_U + 0.662 \times A_{Th} + 0.043\,A_k + 0.03 \times A_{Cs} + 34 \qquad (3.4)$$

where A_{Cs} is the activity concentration of ^{137}Cs radionuclide, 0.03 is the conversion factor of ^{137}Cs and the number 34 is a factor included to ensure that the cosmic rays effects are implemented.

3.3.3 The annual effective dose equivalent

The annual effective dose equivalent (AEDE) is introduced to assess the health effects resulting from the exposure of human body to γ-radiations.

In assessing the annual effective doses, the following factors must be taken into consideration: (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor and outdoor occupancy factors. The average numerical values of those parameters may vary with the age of the population and the climate at the location considered (Alharbi et al., 2011).

The annual effective dose equivalent (AEDE) to an adult can be calculated using the conversion coefficient from absorbed dose in air to effective dose received by an adult annually. The value of this conversion coefficient is 0.7 Sv/Gy as reported in (UNSCEAR, 1982). Moreover, calculations using Monte Carlo radiation-transport codes indicate that higher conversion values should be used for infants and children. According to UNSCEAR report it is 0.9 Sv Gy^{-1} for infants and 0.8 Sv Gy^{-1} for children (UNSCEAR, 2000).

In this study, the annual effective dose equivalent will be calculated for adults only. The calculation of annual effective dose equivalent needs the values of the outdoor and indoor occupancy factors. These values are assessed worldwide, by considering the people in investigated region spend 80% of their times indoor and 20% of their times outdoor

within 8760 hrs of the annually accumulative time . Values of 0.2 and 0.8 are adopted as outdoor and indoor occupancy factors respectively (UNSCEAR , 2000; 1993) .

Besides the ratio of indoor to outdoor gamma dose rates is approximately 1.4. This value was used by other investigators (Huy and Luyen, 2005; Dabayneh et al., 2008; UNSCEAR, 2000; Svoukis and Tsertos, 2007). Therefore, the annual effective doses outdoors and indoors equivalent to an adult are calculated using the following equations (Huy and Luyen, 2005; Choudhury et al., 2005):

$$D_{outdoor}(mSvy^{-1}) = D_r(mGyh^{-1}) \times 24h \times 365.25d \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \quad (3.5)$$

$$D_{indoor}(mSvy^{-1}) = D_r(mGyh^{-1}) \times 24h \times 365.25d \times 1.4 \times 0.8 \times 0.7SvGy^{-1} \times 10^{-6} \quad (3.6)$$

$$D_{total}\ (m\,Sv\,y^{-1}) = D_{outdoor} + D_{indoor} \quad (3.7)$$

3.3.4 External Hazard index

The external hazard index, $H_{ex,}$ is an evaluation of the hazard level from the external exposure to natural γ-radiation (El-Tahawy and Higgy, 1995). This index is calculated for the emitted γ -rays from radio-nuclides in the soil samples from Ra_{eq} on the assumption that its allowed maximum value is equal to unity corresponding to the upper limit of Ra_{eq} which is equal to 370 Bq/kg (Mahur et al., 2010). Therefore, H_{ex} can be calculated according to the following semi empirical formula (Beretka and Mathew, 1985; Alharbi et al., 2011; Al-Trabulsy et al., 2011 ; Thabayneh and Jazzar, 2012):

$$H_{ex} = \frac{A_U}{370\ Bq\ /\ kg} + \frac{A_{Th}}{259\ Bq\ /\ kg} + \frac{A_K}{4810\ Bq\ /\ kg} \leq 1 \quad (3.8)$$

Values of H_{ex} should be lower than unity in order to keep the radiation hazard insignificant (Huy and Luyen, 2005; Mahur et al., 2010).

3.3.5 Internal Hazard index

The hazard levels from the inhalation of alpha particles emitted from the short lived radio-nuclides radon (^{222}Rn , the daughter product of ^{226}Ra) and thoron (^{220}Rn , the daughter product of ^{224}Ra) can be quantified by the internal hazard index, H_{in} . This index can be calculated using the following semi empirical formula (Beretka and Mathew,1985 Rafique et al., 2011; Mahur et al., 2010; Alharbi et al., 2011 ; Al-Trabulsy et al., 2011 ; Thabayneh and Jazzar, 2012):

$$Hin = \frac{A_U}{185\ Bq/kg} + \frac{A_{Th}}{259\ Bq/kg} + \frac{A_K}{4810\ Bq/kg} \leq 1 \qquad (3.9)$$

The internal hazard index must be less than unity to provide safe levels of radon and its short-lived daughters for the respiratory organs of humans living in the dwellings.

3.3.6 Radioactivity level index

The radioactivity level index, I_γ, is generally used to assess the hazard level on human health as a result of exposure to an amount of external (indoor or outdoor) annual effective dose of γ-radiation caused by radio-nuclides in soil samples. This index is important for controlling the annual effective doses come from γ- radiation to prevent the human body from exposing to high doses which above the global permissible value (Al- Saleh and Al-Berzan, 2007).

Iγ can be calculated according to the following semi - empirical formula (Dabayneh et al., 2008; Al-Trabulsy et al., 2011 ; Thabayneh and Jazzar, 2012):

$$I_\gamma = \frac{A_U}{150\ Bq/kg} + \frac{A_{Th}}{100\ Bq/kg} + \frac{A_K}{1500\ Bq/kg} \leq 1 \qquad (3.10)$$

Equations (3.1)-(3.10) will be used in obtaining the data necessary to be used as a baseline for the natural radioactive concentration in soil material of Bethlehem governorate.

Chapter Four

Results and Discussion

Chapter Four
Results and Discussion

4.1 Introduction

In this chapter, the activity concentration levels of γ- radiations and their doses are calculated using the experimental data obtained from the experimental investigations conducted on soil samples collected from different sites in Bethlehem governorate in Chapter two. The reported values of the activity concentration levels of γ- radiations and their doses will be discussed and be compared with the corresponding measured international values in order to judge whether the inspected region is radioactive contaminant or not.

4.2 The activity concentration levels of radio-nuclides

The activity concentration levels of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in the collected soil samples from different locations of Bethlehem governorate were calculated using equation (3.1) and were listed in Appendix B. These results are summarized in the following Table:

Table 4.1: Summary of the activity concentration levels(Bq/kg) of radio-nuclides in soil of Bethlehem governorate (± standard deviation).

Element	Range	Average	Worldwide range (UNSCEAR,2000)	Worldwide average (UNSCEAR,2000)
A_U	12.7-122.3	41.4±23.4	17 – 60	35
A_{Th}	1.8-32.2	19.5±8.1	11 – 64	30
A_K	1.6-183.8	113.3±47.4	140 – 850	400
A_{Cs}	0.2-12.2	2.4 ±2.3	Compare with other worldwide values in Table 4.4	

As shown in this Table the obtained average value of the activity concentration of ^{238}U, A_U ,is higher than the permissible global value. But the average values of the activity

concentration of ^{232}Th, A_{Th}, and ^{40}K , A_K, are less than the corresponding worldwide average values.

The main source of the manmade fission product residue , ^{137}Cs, which is detected in most locations in Bethlehem governorate is global fallout from the atmosphere as a result of atmospheric nuclear weapons testing and accidental release from nuclear facilities such as Chernobyl accident and the routine discharge of radio-nuclides from nuclear installations (Mirkhani et al., 2010; Kabir et al., 2009). Whereas after a nuclear explosion the radioactive fission products such as ^{137}Cs will be blown by upper winds many thousands of miles to other places and then it goes down slowly and deposit on the earth's surface (UNSCEAR, 2000). Moreover, the obtained range of the activity concentration of ^{137}Cs, A_{Cs} fall within the middle range of other published results mentioned in Table 4.4.

4.3 Radiological effect parameters

The radiological effect parameters such as: the absorbed dose rate of natural radio-nuclides, D_r, the absorbed dose rate of natural radio-nuclides, ^{137}Cs and cosmic radiation, D_γ, the outdoor annual effective dose rate, $D_{outdoor}$ the indoor annual effective dose rate, D_{indoor} ,the total annual effective dose rate, D_{total}, the external and internal hazard index and radioactivity level index of the soil samples collected from region under investigation were calculated using equations (3.2)-(3.10). The resulting values of these parameters were listed in Appendix C. The results are summarized in the following Table:

Table 4.2: Summary of the radiological effect parameters in soil of Bethlehem governorate (± standard deviation).

Parameter value	Range	Average	Worldwide average (UNSCEAR,2000)
D_r nGy/h	7.1-64.5	35.3 ±12.7	57
D_γ nGy/h	41.1-98.6	69.3±12.7	
$D_{outdoor}$ mSv/y	0.01-0.08	0.04±0.02	0.07
D_{indoor} mSv/y	0.05-0.44	0.24±0.09	0.41
D_{total} mSv/y	0.06-0.52	0.28±0.10	0.48
Ra_{eq} Bq/kg	16.3-147.9	77.6±28.6	370
H_{ex}	0.04-0.40	0.21±0.08	1
H_{in}	0.08-0.73	0.32±0.14	1
I_γ	0.11-1.00	0.55±0.20	1

As shown in Table 4.2 the obtained average values of D_r, D_γ, $D_{outdoor}$, D_{indoor}, D_{total}, Ra_{eq}, H_{ex}, H_{in}, and I_γ fall within the range of corresponding worldwide average values.

4.4 A comparison between the activity levels of radio-nuclides obtained from this study with those of other countries

This section outlines some previous studies on the levels of natural radio-nuclides and anthropogenic radionuclide ^{137}Cs in soil samples taken from various countries in the world. For the sake of comparison, the levels of the natural radio-nuclides in the soil samples of various other countries are exhibited in Table 4.3.

As shown in this Table, the average of the activity concentration level of ^{238}U obtained from this study is less than the corresponding values of some other countries such as Jordan, Malaysia, Thailand, Portugal and the south west bank in Palestine. Also, it is observed that the average activity concentration level of ^{238}U obtained from this study is

higher than the corresponding values of some other countries such as Algeria, Oman, Syria, Libya and Kuwait.

By looking to the Table 4.3, it can be seen that the activity concentration levels of ^{232}Th and ^{40}K and the average values of the absorbed dose rates obtained from this study fall within the lowest range of the most reported values from other worldwide and neighbouring countries. Table 4.4 shows the ^{137}Cs activity concentration ranges reported from some of other countries in the world and the region under investigation in the present study. The ^{137}Cs activity concentration range reported in this study was compared with the corresponding ranges in other countries listed in Table 4.4.

It can be seen from this Table that the ^{137}Cs activity concentration range obtained from this study is lower than that of some countries such as Egypt, Algeria, Taiwan and the south of West Bank, Palestine and higher than that of other countries such as Libya, Saudi Arabia, Spain and Bangladesh .

Table 4.3 : A comparison of natural radioactivity levels in soil samples under investigation with those in other countries

Country	Activity Concentration (Bq/Kg)						Absorbed dose rate in air (nGy/h)		Ref.
	^{238}U		^{232}Th		^{40}K		Range	Mean	
	Range	Mean	Range	Mean	Range	Mean			
Jordan		49.9		26.7		291.1		51.5	(Al-Hamarneh Awadallah, 2009)
Algeria	2-110	30	2-140	25	66-1150	370	20-133	70	(UNSCEAR,2000)
Egypt	6-120	37	2-96	18	29-650	320	8-93	32	(UNSCEAR,2000)
Oman		29.7		15.9		225		39.8	(Goddard, 2002)
Syria	10-64	23	10-32	20	87-780	270	52-67	59	(UNSCEAR, 2000)
Libya	8.7-12.8	10.5	7.6-9.7	9.5	265-282	270		23	(Shenber, 1997)
Kuwait	1.8-28	11.8	1.5-16	10	4-497	332			(Bou-Rabee,1997)
Saudi Arabia		14.5		11.2		225		23.3	Alaamer,2008)
Sudan		20.11		19.1		280.3			(Sam et al.,1997)
China	2-690	33	1-360	41	9-1800	440	2-340	62	(UNSCEAR,2000)
India	7-81	29	14-160	64	38-760	400	20-110	56	(UNSCEAR,2000)
Iran	8-55	28	5-42	22	250-980	640	36-130	71	(UNSCEAR,2000)
Denemark	9-29	17	8-30	19	240-610	460	35-70	52	(UNSCEAR,2000)
Poland	5-120	26	4-77	21	110-970	410	18-97	45	(UNSCEAR,2000)
Greece	1-240	25	1-190	21	12-1570	360	30-109	56	(UNSCEAR,2000)
Germany	11-330		7-134		40-1340		4-350	50	(UNSCEAR,2000)
Romania	8-60	32	11-75	38	250-1100	490	21-122	59	(UNSCEAR,2000)
Spain	6-250	32	2-210	33	25-1650	470	40-120	76	(UNSCEAR,2000)
Malaysia	49-86	66	63-110	82	170-430	310	55-130	92	(UNSCEAR,2000)
Cyprus	0-120	17			0-670	140	9-52	18	(UNSCEAR, 2000)
Turkey		21		37		342		65	Karahan Bayulken ,2000)
USA	4-140	35	4-130	35	100-700	370	14-118	47	(UNSCEAR,2000)
Hong Kong	30-110		1.9-243		59-851			76	(Leung et al.,1990)
Switzerland	10-150	40	4-70	25	40-1000	370	15-120	45	(UNSCEAR, 2000)
Italy	15-164		16-174		201-1350				(Bellia et al, 1997)
Thailand	3-370	114	7-120	51	7-712	230	2-100	77	(UNSCEAR,2000)
Portugal	26-82	49	22-100	51	220-1230	840	4-230	84	(UNSCEAR, 2000)
South WB (Hebron)	33-105	69	15-77	48	297-962	630	39-123	88	(Dabaynehet al.,2008)
Present study	12.7-122.3	41.4	1.8-32	19.5	1.6-183.8	113.3	7.1-64.5	35.3	
Worldwide		35		30		400		51	(UNSCEAR, 2000)

Table 4.4: Range of activity concentration levels of ^{137}Cs in soil samples reported from some of the other locations in the world (Dabayneh et al.,2008; Tahir et al.,2006; Shizuma et al. ,1996) .

Country	Activity Concentration Range (Bq/kg)
Egypt(Cairo)	1.6-19.1
Algeria	15-35
Sudan	0-18.5
Libya	0.9-1.7
Saudi Arabia (Riyadh)	0-2
Spain (Bay of Cadiz)	0.5-5
Turkey(Kocaelibasin)	2-25
Bangladesh (Savart)	2-3
Taiwan	1.5-27
Pakistan(Punjab)	1.1-5.3
Japan (Hiroshima)	0.16-10.6
South West Bank (Hebron)	1.8-36.1
Present Study	0.2-12.2

Chapter Five

Conclusions and Recommendations

Chapter Five
Conclusions and Recommendations

5.1 Conclusions

Gamma ray spectrometry was exploited to determine activity concentrations due to naturally occurring ^{238}U, ^{232}Th and ^{40}K radio-nuclides and artificial ^{137}Cs radionuclide and the associated radiation hazard levels in 50 of soil samples selected randomly from areas in the 24 different locations of Bethlehem governorate in West Back-Palestine. The average activity concentrations for ^{238}U series, ^{232}Th series, ^{40}K and ^{137}Cs are respectively. in Bq/kg 41.4±23.4; 19.5±8.1; 113.3±47.4; and 2.4±2.3 .

The average activity concentrations of ^{232}Th and ^{40}K were lower than the world average of 30 Bq/kg and 400 Bq/kg for ^{232}Th and ^{40}K respectively. But the average activity of ^{238}U series was higher than the corresponding world average of 35 Bq/kg. It is concluded that the areas under investigation in Bethlehem governorate have a normal level of natural B.G. radiation and so there are no harmful radiation effects were posed to the population who live in the study area. But environmental protection rules are required to reduce radioactive pollution in regions having high activity concentrations of ^{238}U, which have danger impacts on human health.

The average dose rates and other calculated hazard indices were lower than the average national and world recommended values, therefore, did not pose health risks to the population of the area. The average of total annual effective dose equivalent was 0.28±0.10 mSv/y which was lower than the 0.48 mSv/y dose limit recommended by the (UNSCEAR,2000) for public radiation exposure control.

5.2 Recommendations for further studies

Since few studies on natural radioactivity concentration measurements are reported in Palestine. We suggest the following recommendations for further studies:

- Perform similar studies for samples from different depths of soil to clarify their effects on natural radioactivity concentrations in soil.
- Conduct studies using soil samples with grains of different sizes to clarify their effects on natural radioactivity concentrations in soil.
- Focus on the measurement of natural radioactivity concentrations in cultivated lands with different types of plants to determine the impact of plant type on the radioactivity concentrations in soil which they are grown in it.
- Survey other governorates in Palestine to establish a baseline map of radioactivity concentration levels and determine the values of radiological effect parameters.
- Conduct similar studies in other environmental samples as water and foodstuff.

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Appendix A

Description of the sites from where the soil samples were collected.

Sample Code	Collection site	Description of the collection site	Collection date
BS1	Yard of French hospital.	Land planted with ornamental trees at the middle of the hospital yard.	1/4/2011
BS2	Atan st. Nativity Church.	Land planted with flowers and palm.	1/4/2011
BS3	Northern entrance of Bethlehem.	Garden planted with orange seedlings near crossing road.	1/4/2011
BS4	Old Beit Jala	Land planted with olives near buildings at the middle of Beit Jala	1/4/2011
BS5	Beit Jala (Bir Onah)	Land planted with olives at the north of Beit Jala	1/4/2011
BS6	Beit Sahour (Al Isier)	Flat land plowed and not planted at the north of Beit Sahour.	1/4/2011
BS7	Beit Sahour	Mountainous land planted with herbs and thorns at the south of Beit Sahour.	1/4/2011
BS8	Beit Sahour	Flat land planted with lemons and almonds at the east of Beit Sahour.	1/4/2011
BS9	Al Doha	Land planted with olives near buildings at the middle of Al Doha.	1/4/2011
BS10	Al Doheisha Camp	Barren land near buildings located on the main street at the middle of Al Doheisha Camp.	1/4/2011
BS11	Al Khader	Barren land at the north of Al Khader.	1/4/2011
BS12	Al Khader	Land planted with olives at the eastern entrance of Al Khader.	1/4/2011
BS13	Artas	Barren land near buildings at the north east of Artas.	1/4/2011
BS14	Artas	Land planted with pine at the neighbour of Salesman's Pools.	1/4/2011
BS15	Tuku'	Mountainous land planted with herbs at the east of Tuku'.	1/4/2011
BS16	Tuku'	Flat land plowed and planted with olives at the south of Tuku'.	1/4/2011
BS17	Za'tara	Plowed , flat and not panted land at the north of	1/4/2011

		Za'tara.	
BS18	Freedees Mount	Plowed , flat and not planted land around Freedees Mount.	1/4/2011
BS19	Al Shawawra	Not planted Valley at the south of Al Shawawra.	1/4/2011
BS20	Al Shawawra (Al Baidah)	Orchard planted with lemons and almonds at the west of Al Shawawra.	1/4/2011
BS21	Al Shawawra	Land planted with herbs at the North of Al Shawawra	1/4/2011
BS22	Al Shawawra (Al Muttal')	Mountainous and not planted land at the middle of Al Shawawra.	1/4/2011
BS23	Dar Salah	Land planted with olives at the middle of Dar Salah.	1/4/2011
BS24	Dar Salah	Barren land at the north of Dar Salah.	1/4/2011
BS25	Al Obeidiya	Land planted with herbs near buildings at the southern entrance of Al Obeidiya.	1/4/2011
BS26	Al Obeidiya	Barren land at the north of Al Obeidiya on the side of the road (near the door of monastery).	1/4/2011
BS27	Al Obeidiya (Al Asasweh)	Flat land planted with olives at the middle of Al Obeidiya.	1/4/2011
BS28	Wad Al Nar	Barren land at the south of Abu Dies near the Israeli checkpoint.	1/4/2011
BS29	Wad Al Nar	Barren land at the south of Wad Al Nar.	1/4/2011
BS30	Wad Al Nar	Barren land near brick factory at the middle of Wad Al Nar.	1/4/2011
BS31	Al Sawahra	Mountainous land at the middle of Al Wad street.	1/4/2011
BS32	Al Sawahra	Hill planted with pine at the south of Al Sawahra.	1/4/2011
BS33	Abu Dies	Palestine garden planted with pine and ornamental trees at Al Quds university.	1/5/2011
BS34	Sur Bahir	Land planted with olives at the south of Sur Bahir .	19/4/2011
BS35	Sur Bahir	Barren land at the north of Sur Bahir .	19/4/2011
BS36	Jurat Al Sham'a	Powder quarry at the middle of Jurat Al Sham'a.	1/4/2011
BS37	Jurat Al Sham'a	Plowed land planted with almonds at the south of Jurat Al Sham'a.	1/4/2011

BS38	Beit Fajjar	Powder quarry (Samih Hamdan quarry) at the south of Beit Fajjar.	1/4/2011
BS39	Beit Fajjar	Powder quarry (Khallit Hijji quarry) at the east of Beit Fajjar.	1/4/2011
BS40	Beit Fajjar	Barren land near quarry at the middle of Beit Fajjar.	1/4/2011
BS41	Al Jab'a	Land planted with thorns at the west of Al Jab'a.	1/4/2011
BS42	Al Jab'a	Hill planted with olives at the middle of Al Jab'a.	1/4/2011
BS43	Nahhalin	Barren land at the north of Nahhalin.	1/4/2011
BS44	Nahhalin	Forest land planted with pine at the west of Nahhalin.	1/4/2011
BS45	Wad Fukin	Plowed and not planted land at the eastern entrance of Wad Fukin.	1/4/2011
BS46	Wad Fukin (Al Basateen region)	Flat and planted land with grapes at the middle of Wad Fukin.	1/4/2011
BS47	Husan	Flat and planted land with herbs at the south of Husan.	1/4/2011
BS48	Husan	Plowed and not planted land at the north of Husan.	1/4/2011
BS49	Battir (Al Makhroor)	Mountainous area planted with olives and almonds at the north of Battir.	1/4/2011
BS50	Battir (Al Mahatta land)	Land planted with olives and almonds near the border region beside the railway.	1/4/2011

Appendix B

The activity concentration levels of radio-nuclides in soil samples collected from different sites located in Bethlehem governorate.

Zone	Sample code	Activity concentration (Bq/kg)			
		^{238}U	^{232}Th	^{40}K	^{137}Cs
Bethlehem city	BS1	31.8	18.7	115.2	Not detected
	BS2	18.8	11.2	69.4	0.4
	BS3	41.8	23.9	149.8	2.9
	Average	30.8	17.9	115.5	1.1
Beit Jala	BS4	31.6	12.3	61.4	0.9
	BS5	13.4	7.5	74.8	0.3
	Average	22.5	9.9	68.1	0.6
Beit Sahour	BS6	55.5	23.6	127.8	0.9
	BS7	47.3	16.9	88.2	1.7
	BS8	27.4	23.4	118.7	0.9
	Average	43.4	21.3	111.6	1.2
Al Doha	BS9	32.4	24.3	92.5	1.5
Al Duheisha Camp	BS10	47.1	27.2	155.6	Not detected
Al Khader	BS11	45.1	30.9	175.6	2.9
	BS12	52.0	18.9	123.7	5.0
	Average	48.6	24.9	149.7	4.0
Artas	BS13	12.7	7.3	50.8	2.5
	BS14	37.0	23.2	176.4	5.5
	Average	24.9	15.3	113.6	4.0
Tuku'	BS15	30.0	31.2	166.4	2.8
	BS16	40.9	27.3	179.6	2.6
	Average	35.5	29.3	173.0	2.7
Za'tara	BS17	36.7	18.9	183.8	0.3
Freedees mount	BS18	45.8	12.1	81.9	3.0

Al Shawawra	BS19	89.7	22.7	132.8	4.5
	BS20	21.2	19.0	115.6	0.2
	BS21	50.8	24.4	156.2	3.4
	BS22	61.1	13.8	99.5	3.2
	Average	55.7	20.0	126.0	2.8
Dar Salah	BS23	41.8	11.4	61.0	0.8
	BS24	122.3	14.9	56.2	3.9
	Average	82.1	13.2	58.6	2.4
Al Obeidiya	BS25	30.2	17.5	149.3	2.3
	BS26	71.4	12.4	163.6	2.0
	BS27	27.0	20.6	136.9	0.9
	Average	42.9	16.8	149.9	1.7
Wad Al Nar	BS28	99.4	12.4	48.3	3.1
	BS29	93.8	8.1	35.4	3.2
	BS30	88.5	10.5	33.0	4.3
	Average	93.9	10.3	38.9	3.5
Al Sawahra	BS31	69.8	19.4	101.8	3.3
	BS32	42.5	22.0	108.2	4.2
	Average	56.2	20.7	105	3.8
Abu Dies	BS33	33.9	25.4	157.3	0.9
Sur Bahir	BS34	44.6	18.1	86.9	0.9
	BS35	50.9	30.7	128.7	1.0
	Average	47.8	24.4	107.8	1.0
Jurat Al sham'a	BS36	13.2	1.8	6.5	Not detected
	BS37	40.8	27.9	133.8	0.8
	average	27.0	14.9	70.2	0.4
Beit Fajjar	BS38	17.3	3.0	1.6	Not detected
	BS39	14.3	5.5	23.1	0.3
	BS40	22.0	12.3	64.0	1.1
	average	17.9	6.9	29.6	0.5

Al Jab'a	BS41	47.3	31.4	168	12.2
	BS42	51.0	27.3	162.3	7.5
	Average	49.2	29.4	165.2	9.9
Nahhalin	BS43	33.2	7.7	92.9	0.2
	BS44	43.9	20.8	114.9	5.4
	Average	38.6	14.3	103.9	2.8
Wadi Fukin	BS45	63.9	30.5	122.6	1.4
	BS46	34.2	27.4	136.1	1.6
	Average	49.1	29.0	129.4	1.5
Husan	BS47	25.1	7.6	78.1	0.4
	BS48	39.9	32.2	134.9	2.1
	Average	32.5	19.9	106.5	1.3
Battir	BS49	36.2	17.1	149.7	6.1
	BS50	18.5	21.5	137.2	5.9
	Average	27.4	19.3	143.5	6.0

Appendix C

Radiological effect parameters for radio-nuclides in soil samples collected from different sites located in Bethlehem governorate.

Zone	Sample code	D_r (nGy/h)	D_γ (nGy/h)	$D_{outdoor}$ (mSv/y)	D_{indoor} (mSv/y)	D_{total} (mSv/y)
Bethlehem town	BS1	30.9	64.9	0.04	0.21	0.25
	BS2	18.4	52.4	0.02	0.13	0.15
	BS3	40.1	74.2	0.05	0.28	0.33
	Average	29.8	63.8	0.04	0.20	0.24
Beit Jala	BS4	24.2	58.3	0.03	0.17	0.20
	BS5	13.9	47.9	0.02	0.10	0.12
	Average	19.1	53.1	0.02	0.13	0.15
Beit Sahour	BS6	44.8	78.8	0.05	0.31	0.36
	BS7	35.1	69.2	0.04	0.24	0.28
	BS8	32.3	66.3	0.04	0.22	0.26
	Average	37.4	71.4	0.05	0.26	0.31
Al Doha	BS9	33.9	67.9	0.04	0.23	0.27
Duheisha	BS10	44.8	78.9	0.05	0.31	0.36
Al Khader	BS11	47.2	81.3	0.06	0.32	0.38
	BS12	40.1	74.2	0.05	0.28	0.33
	Average	43.7	77.8	0.05	0.30	0.35
Artas	BS13	12.5	46.5	0.02	0.09	0.11
	BS14	38.7	72.9	0.05	0.27	0.32
	Average	25.6	59.7	0.03	0.18	0.21
Tuku'	BS15	40.6	74.7	0.05	0.28	0.33
	BS16	43.2	77.3	0.05	0.30	0.35
	Average	41.9	76.0	0.05	0.29	0.34
Za'tara	BS17	36.1	70.1	0.04	0.25	0.29
Freedees mount	BS18	31.1	65.2	0.04	0.21	0.25
Al Shawawra	BS19	59.1	93.2	0.07	0.41	0.48
	BS20	26.6	60.6	0.03	0.18	0.21
	BS21	44.6	78.7	0.05	0.31	0.36
	BS22	39.5	73.6	0.05	0.27	0.32
	Average	42.5	76.5	0.05	0.29	0.34
Dar Salah	BS23	28.0	62.0	0.03	0.19	0.22
	BS24	64.5	98.6	0.08	0.44	0.52
	Average	46.3	80.3	0.06	0.32	0.38

Al Obeidiya	BS25	30.9	65.0	0.04	0.21	0.25
	BS26	45.7	79.8	0.06	0.31	0.37
	BS27	31.1	65.1	0.04	0.21	0.25
	Average	35.9	70.0	0.04	0.25	0.29
Wad Al Nar	BS28	52.8	86.9	0.06	0.36	0.42
	BS29	47.0	81.0	0.06	0.32	0.38
	BS30	46.2	80.3	0.06	0.32	0.38
	Average	48.7	82.7	0.06	0.33	0.39
Al Sawahra	BS31	47.0	81.1	0.06	0.32	0.38
	BS32	37.4	71.5	0.05	0.26	0.31
	Average	42.2	76.3	0.05	0.29	0.34
Abu Dies	BS33	38.1	72.1	0.05	0.26	0.31
Sur Bahir	BS34	34.8	68.8	0.04	0.24	0.28
	BS35	47.6	81.6	0.06	0.33	0.39
	Average	41.2	75.2	0.05	0.28	0.33
Jurat Al Sham'a	BS36	7.1	41.1	0.01	0.05	0.06
	BS37	41.7	75.7	0.05	0.29	0.34
	Average	24.5	58.4	0.03	0.17	0.20
Beit Fajjar	BS38	9.4	43.4	0.01	0.06	0.07
	BS39	10.8	44.8	0.01	0.07	0.08
	BS40	20.3	54.3	0.02	0.14	0.16
	Average	13.5	47.5	0.02	0.09	0.11
Al Jab'a	BS41	48.2	82.6	0.06	0.33	0.39
	BS42	46.8	81.1	0.06	0.32	0.38
	Average	47.5	81.9	0.06	0.33	0.39
Nahhalin	BS43	23.3	57.3	0.03	0.16	0.19
	BS44	37.4	71.6	0.05	0.26	0.31
	Average	30.4	64.5	0.04	0.21	0.25
Wadi Fukin	BS45	52.8	86.8	0.06	0.36	0.42
	BS46	38.5	72.6	0.05	0.26	0.31
	Average	45.7	79.7	0.06	0.31	0.37
Husan	BS47	19.1	53.1	0.02	0.13	0.15
	BS48	44.1	78.2	0.05	0.30	0.35
	Average	31.6	65.7	0.04	0.22	0.26
Battir	BS49	33.2	67.4	0.04	0.23	0.27
	BS50	28.0	62.2	0.03	0.19	0.22
	Average	30.6	64.8	0.04	0.21	0.25

Zone	Sample code	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	I_{γ}
Bethlehem town	BS1	67.4	0.18	0.27	0.48
	BS2	40.1	0.11	0.16	0.28
	BS3	87.5	0.24	0.35	0.62
	Average	65.0	0.18	0.26	0.46
Beit Jala	BS4	53.8	0.15	0.23	0.37
	BS5	29.9	0.08	0.12	0.21
	Average	41.9	0.12	0.18	0.29
Beit Sahour	BS6	99.1	0.27	0.42	0.69
	BS7	78.2	0.21	0.34	0.54
	BS8	70.0	0.19	0.26	0.50
	Average	82.4	0.22	0.34	0.58
Al Doha	BS9	74.2	0.20	0.29	0.52
Al Duheisha	BS10	98.1	0.26	0.39	0.69
Al Khader	BS11	102.7	0.28	0.40	0.73
	BS12	88.6	0.24	0.38	0.62
	Average	95.7	0.26	0.39	0.68
Artas	BS13	27.1	0.07	0.11	0.19
	BS14	83.7	0.23	0.33	0.60
	Average	55.4	0.15	0.22	0.40
Tuku'	BS15	87.4	0.24	0.32	0.62
	BS16	93.7	0.25	0.36	0.67
	Average	90.6	0.25	0.34	0.65
Za'tara	BS17	77.9	0.21	0.31	0.56
Freedees mount	BS18	69.4	0.19	0.31	0.48
Al Shawawra	BS19	132.4	0.36	0.60	0.91
	BS20	57.3	0.15	0.21	0.41
	BS21	97.7	0.26	0.40	0.69
	BS22	88.4	0.24	0.40	0.61
	Average	94.0	0.25	0.40	0.66
Dar Salah	BS23	62.7	0.17	0.28	0.43
	BS24	147.9	0.40	0.73	1.00
	Average	105.3	0.29	0.51	0.72
Al Obeidiya	BS25	66.8	0.18	0.26	0.48
	BS26	101.6	0.27	0.47	0.71
	BS27	67.0	0.18	0.25	0.48
	Average	78.5	0.21	0.33	0.56
Wad Al Nar	BS28	120.9	0.33	0.60	0.82
	BS29	108.1	0.29	0.55	0.73
	BS30	106.1	0.29	0.53	0.72
	Average	111.7	0.30	0.56	0.76
Al Sawahra	BS31	105.4	0.28	0.47	0.73
	BS32	82.3	0.22	0.34	0.58
	Average	93.9	0.25	0.41	0.66

Abu Dies	BS33	82.4	0.22	0.31	0.59
Sur Bahir	BS34	77.2	0.21	0.33	0.54
	BS35	104.8	0.28	0.42	0.73
	Average	91.0	0.25	0.38	0.64
Jurat Al Sham'a	BS36	16.3	0.04	0.08	0.11
	BS37	91.0	0.25	0.36	0.64
	Average	53.7	0.15	0.22	0.38
Beit Fajjar	BS38	21.7	0.06	0.11	0.15
	BS39	24.0	0.06	0.10	0.17
	BS40	44.6	0.12	0.18	0.31
	Average	30.1	0.08	0.13	0.21
Al Jab'a	BS41	105.1	0.28	0.41	0.74
	BS42	102.6	0.28	0.41	0.72
	Average	103.9	0.28	0.41	0.73
Nahhalin	BS43	51.4	0.14	0.23	0.36
	BS44	82.4	0.22	0.34	0.58
	Average	66.9	0.18	0.29	0.47
Wadi Fukin	BS45	117.0	0.32	0.49	0.81
	BS46	83.8	0.23	0.32	0.59
	Average	100.4	0.28	0.41	0.70
Husan	BS47	42.0	0.11	0.18	0.30
	BS48	96.3	0.26	0.37	0.68
	Average	69.2	0.19	0.28	0.49
Battir	BS49	72.1	0.19	0.29	0.51
	BS50	59.7	0.16	0.21	0.43
	Average	65.9	0.18	0.25	0.47

مستويات تركيز النشاط الإشعاعي من النويدات المشعة الطبيعية في عينات من تربة منطقة بيت لحم – فلسطين

إعداد فاطمة وليد إبراهيم اخريس

إشراف أ.د. محمد أبو سمرة د. خليل ذبابنة

الملخص

تم في هذه الدراسة قياس تركيز الأنوية المشعة الطبيعية (اليورانيوم-238, الثوريوم-232 و البوتاسيوم – 40) بالإضافة إلى تركيز العنصر الصناعي المشع (السيزيوم-137) في 50 عينة تربة أخذت من مناطق مختلفة من محافظة بيت لحم باستخدام كاشف الجرمانيوم عالي النقاوة. ووجد بأن تركيز كل من اليورانيوم-238, الثوريوم-232 و البوتاسيوم- 40 تراوح ما بين 12, 7 -122, 3, 1, 8- 32, 2 و 1, 6 – 183, 8 بيكريل/كغم و بمعدلات41.4±23.4 ,19.5±8.1 و 113.3±47.4 بيكريل/كغم على الترتيب. ويمكن الاستنتاج أن تركيز الثوريوم-232 و البوتاسيوم- 40 أقل من القيم العالمية المناظرة لها و التي تساوي 30 و 400 بيكريل/كغم على الترتيب. أما تركيز اليورانيوم-238 فقد وجد بأنه أعلى من المتوسط العالمي الذي يساوي 35 بيكريل/كغم. بالنسبة لتركيز السيزيوم-137, فتراوح بين 0 -12,2 بيكريل/كغم بمعدل 2.4±2.3 بيكريل/كغم.

وتم حساب معدل الجرعة الممتصة للنويدات المشعة الطبيعية مساوية 35.3±12.7 نانو جراي/ساعة, ووصل معدل الجرعة إلى 69.3± 12.7 نانو جراي/ساعة بشمول السيزيوم-137 والأشعة الكونية.

وتم حساب الجرعة السنوية الفعالة المرتبطة بالشخص الواحد , مكافئ الراديوم ومؤشر الخطر الخارجي والداخلي ومستوى الإشعاع في المنطقة المدروسة, وكانت معدلاتها 0.28±0.10 ملي سيفرت/سنة 77.6±28.6 بيكريل/كغم, 0.21±0.08, 0.32±0.14, 0.55±0.20 على الترتيب. وهذه القيم أقل من المناظرة لها عالميا

والتي تساوي 0, 48 ملي سيفرت/سنة, 370 بيكريل/كغم و1 لكل من الجرعة السنوية الفعالة المرتبطة بالشخص الواحد, مكافئ الراديوم و مؤشر الخطر الخارجي و الداخلي و مستوى الإشعاع. يمكن القول بأن المحافظة تشهد مستوى إشعاع أقل من المستوى العالمي باستثناء بعض المناطق التي يرتفع فيها تركيز اليورانيوم-238 و السيزيوم-137 في المحافظة.